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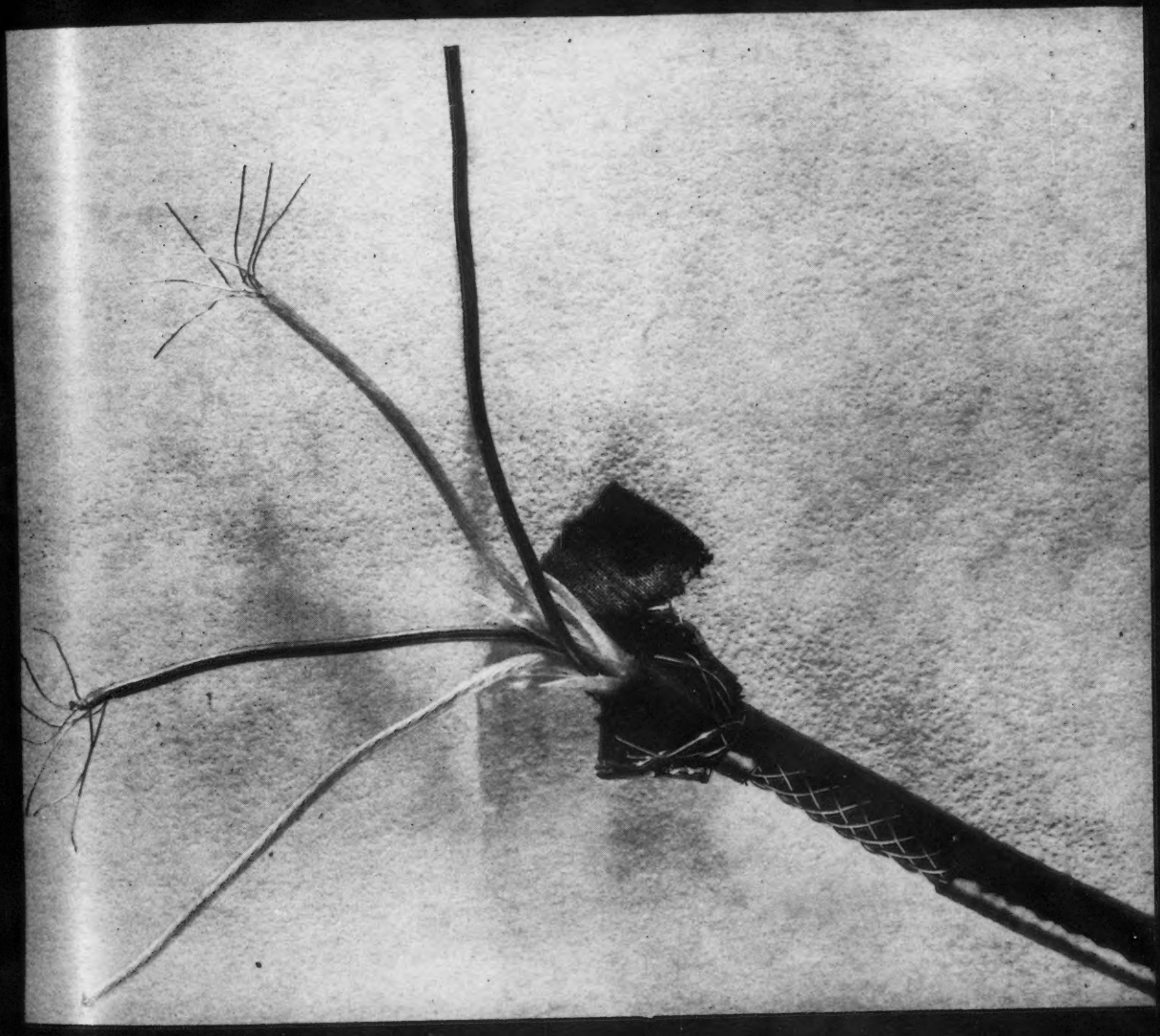

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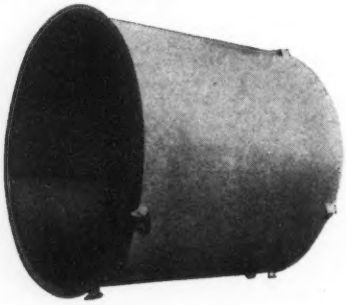

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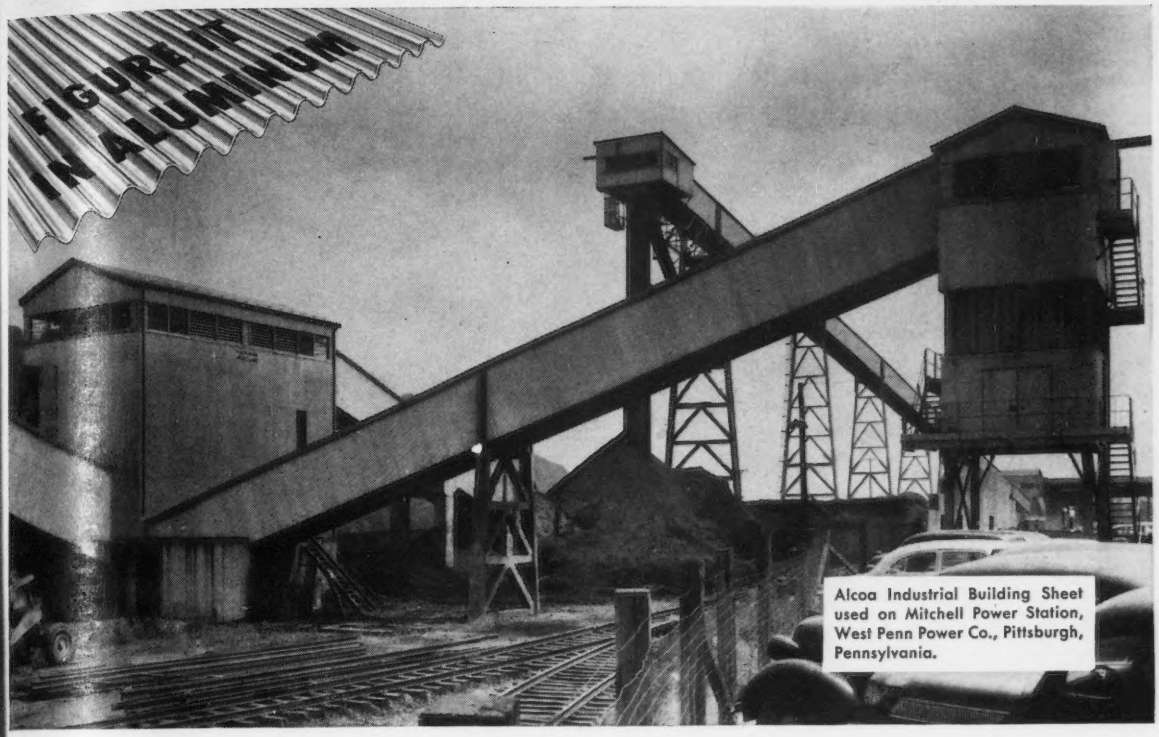

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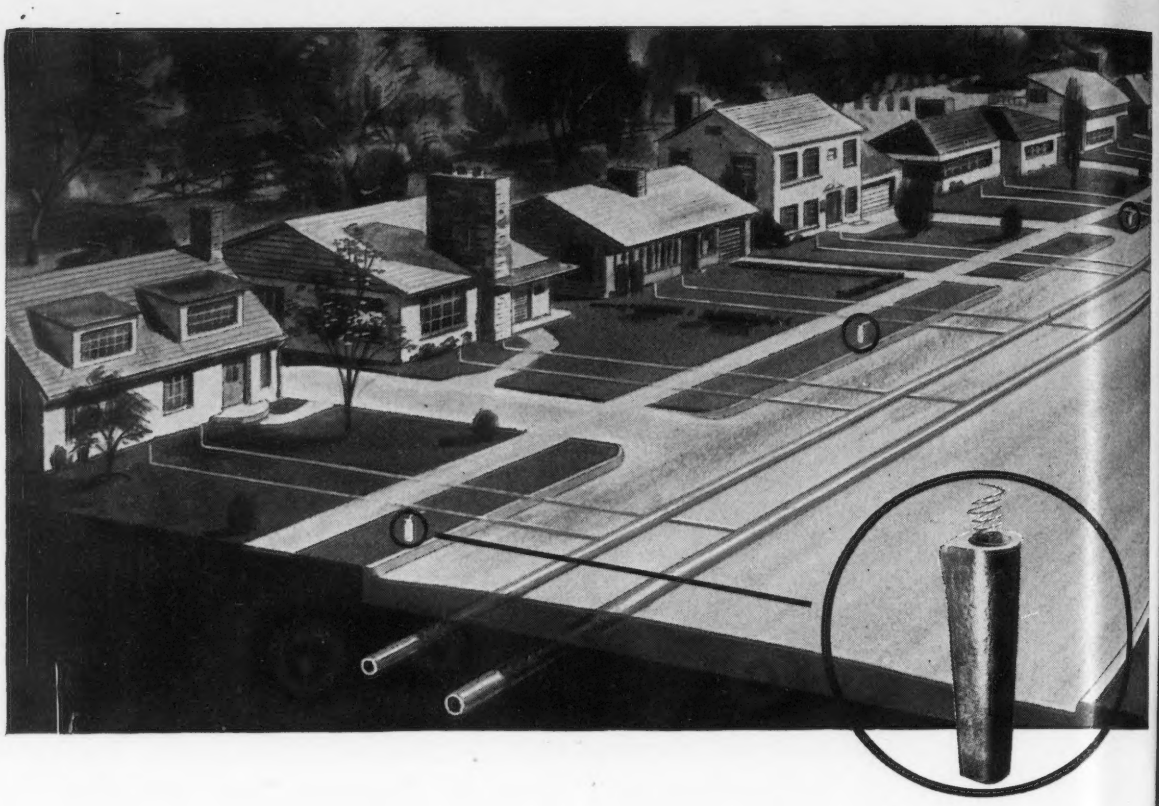

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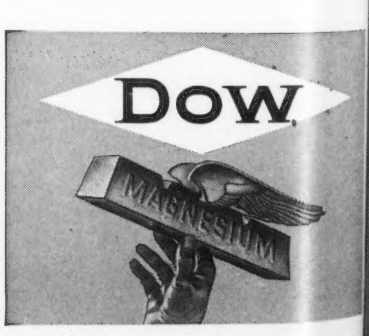

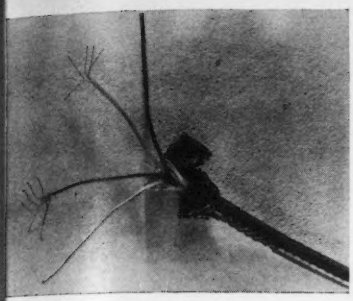

THIS MONTH'S COVER — Extruded Bakelite polyethylene insulation, stainless steel braid and an extruded Vinylite plastic jacket and other improvements give this military carrier cable developed for the Army Signal Corps many advantages over cables formerly used. It can carry up to 12 frequency channels in the range up to 60 kilocycles. Operating temperatures range from 140 degrees down to —67 degrees F. It costs $250 per mile less and weighs 200 pounds less per mile. High resistance of the plastics to abrasion and deformation and attacks by corrosives also are advantageous.

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CORROSION Is Indexed Regularly by Engineering Index.

Corrosion

devoted entirely to
CORROSION
research and control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., as a permanent record of progress in corrosion control.

Vol. 8 — JULY, 1952 — No. 7

CONTENTS

	Page
Directory of NACE Regional and Sectional Officers	iv, v
Directory of Technical Practices Committees	viii, ix
Officers and Directors, National Association of Corrosion Engineers	xiv

TECHNICAL SECTION

	Page
Technical Practices Committee 19—Corrosion by De-Icing Salts *By F. E. Kulman*	225
Aluminum Alloys for Offshore Pipe Lines *By E. T. Wanderer and Donald O. Sprowls*	227
A Hydrogen Evolution Method for Evaluation of Corrosion Inhibitors for Oil Wells *By Willard R. Scott and Gilson H. Rohrback*	234
Vigilance Underground—A Summary of Progress on Preventing Electrochemical Corrosion on Buried Pipe Lines *By Bryan Patterson* Discussion: Page 246	241
Concrete for Sea Water Exposure With Particular Reference to Piling *By Herbert K. Cook*	247
Some Observations on the Potentials of Stainless Steels in Flowing Sea Water *By K. H. Huston and R. B. Teel*	251
Errata	240, 256

NACE REGIONAL AND SECTIONAL NEWS

	Page		Page
New Officers Elected by Western New York Section at Buffalo	1	Keller Elected Head of St. Louis Section	3
Large Gathering Hears Liebman at Philadelphia	1	Five Talk on Plastics at Los Angeles Meeting	3
North Texas Section Hears Talk on Europe	2	Sabine-Neches Section Elects C. A. Murray	3
Boston Section Renames Officers	2	Tulsa Section to Hear Shideler in September	3
Nominations Given for North Central Region	2	Corpus Christi Section Sees Transite Movie	4
Southwestern Ohio Election Results Given	2		

GENERAL NEWS OF CORROSION INTEREST

	Page		Page
Six Symposia Chairmen for Chicago Meeting Named	1	Book Reviews	6
Whitney to Head 1954 Technical Program	1	Radioisotope Tracers Check Bond Mechanism of Porcelain Enamel	6
Vast Savings from Corrosion Control Are Cited	2	Test Data on Asbestos Cement Pipe Compiled	6
Hoxeng Named to Head Publication Committee	2	Corrosion Problems	8
Problem of Internal Corrosion in Pipe Lines Discussed by API Group	4	Results of 2-Year Sheet Metal Corrosion Tests Given	10
Fourth Meeting of CITCE Sept. 10-13	6	NACE New Members and Changes of Address	12
		New Products and Personals	18
INDEX TO CORROSION ABSTRACTS			21
INDEX TO ADVERTISERS			48

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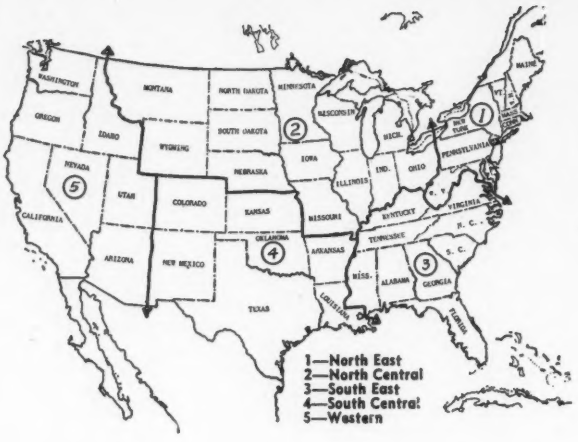

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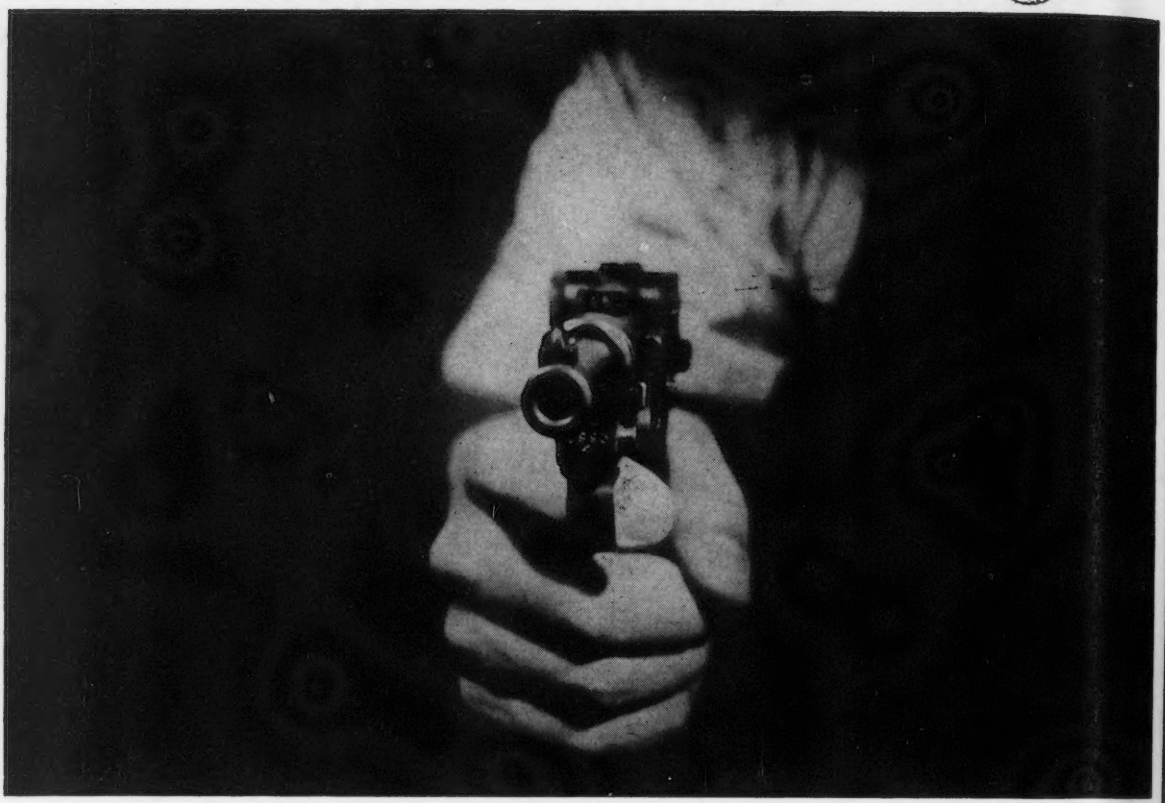
The Editorial Review Committee and the Editor of Corrosion welcome the submission of technical articles on corrosion regardless of their length or content.

Persons interested in submitting material for publication are invited to write for "Guide for Preparation and Presentation of Papers," which gives complete information on the requirements of the association.

You can't stop a bullet with a catcher's mitt



You can't stop corrosion with ordinary paints...

it takes BITUMASTIC COATINGS!

CORROSION can't be stopped by ordinary paints or conventional protective coatings. They can't protect surfaces against the ravages of rust for any appreciable length of time.

But Bitumastic Coatings can!

BECAUSE the six Bitumastic® Protective Coatings, unlike maintenance paints, are specially formulated from a coal-tar pitch base* that is, for all practical purposes, impervious to water. And when you keep moisture away from an exposed surface, you *stop* corrosion.

BECAUSE Bitumastic Coatings provide an extra-tough, extra-thick barrier against corrosive elements—a barrier that is impenetrable.

BECAUSE Bitumastic Coatings provide up to 8 times the film thickness of conventional paint coatings.

BECAUSE Bitumastic Coatings stop corrosion caused by moisture—acid fumes—alkaline fumes—corrosive soil—salt air—heat.

There are 6 Koppers Coatings—formulated to control corrosion of metal and deterioration of concrete. Use the coupon for full information.

**Hi-Heat Gray contains heat-resistant metallic base.*

SEND FOR SET OF FREE BOOKLETS!

Koppers Company, Inc.
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Dept. 704-T, Pittsburgh 19, Pa.

Please send me, without charge or obligation, your booklets on corrosion prevention.

Name.....

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City.....Zone.....State.....

KOPPERS BITUMASTIC PROTECTIVE COATINGS

REG. U.S. PAT. OFF.

SOLD THROUGH INDUSTRIAL DISTRIBUTORS

KOPPERS COMPANY, INC., Tar Products Division, Dept. 704-T, Pittsburgh 19, Pa.

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When planning a pipe-line project—

THINK ABOUT PROTECTION!

Bitumastic Enamel being machine-applied

● When planning a new pipe line, it's wise to include Bitumastic Enamel in your original plans. These coal-tar enamels have established remarkable records for preventing corrosion . . . they have *proved* what they can do. Many oil and gas pipe lines—laid in the nineteen twenties — are still giving good service today, thanks to these durable enamels.

There are many reasons why Bitumastic Enamels are the best barrier against corrosion. Here's an important one: through the years, Bitumastic Enamels keep moisture away from pipe-line surfaces, and that prevents corrosion. *Ordinary* protective coatings just can't keep out moisture year after year.

Specify Bitumastic Enamels for *your* next pipe-line project. It's the sure way to guard against corrosion. For complete details and estimates, get in touch with one of our representatives.

Bitumastic Enamels soon available from Koppers new California Plant!

As soon as present construction work is completed, Koppers will be able to supply Bitumastic Enamels from a new plant at Fontana, California. The plant is being built to give you better service in the West.

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TP-16D Tests and Surveys. L. J. Gorman, Chairman, Robin Beach Engineers Associated, 32 Court St., Brooklyn 2, N. Y. Frank E. Kulman, Co-chairman, Consolidated Edison Co. of New York, 4 Irving Place, New York 3, N. Y.

TP-16E Corrosion and Protection of Pipe-Type Cables. Frank Kahn, Chairman, Philadelphia Electric Co., 2301 Market St., Philadelphia 3, Pa.

TP-16F Nonmetallic Sheath Coatings. Geo. H. Hunt, Chairman, Simplex Wire & Cable Co., 79 Sidney St., Cambridge 39, Mass.

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(Continued from Page viii)

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APPROVED MANUSCRIPTS

Corrosion Resisting Characteristics of Iron Modified 90:10 Cupro Nickel Alloy by W. C. Stewart and F. L. LaQue. Galveston No. 33.

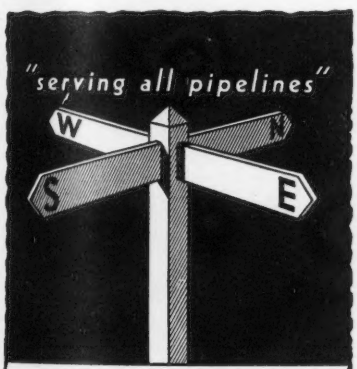
Some Corrosion Experiences With Aluminum Crude Oil Lines by Almont Ellis. Corpus Christi Regional Meeting, 1951.

Why Power Companies Should Promote Corrosion Control by H. H. Anderson.

Corrosion by Fluorine and Fluorine Compounds by Ralph Landau. Galveston No. 7.

Potential Measurements in Cathodic Protection Designs by R. P. Howell. Western Region Meeting, 1951.

Sour Oil Well Corrosion by J. A. Caldwell. Galveston No. 13.



PIPELINE COATINGS
and
WRAPPING MATERIALS

S. D. DAY COMPANY

1973 WEST GRAY HOUSTON, TEXAS PHONE JU-2431

AMERICAN CHEMICAL PAINT COMPANY
AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet
Subject: PROTECTING ALUMINUM WITH ALODINE®

"ALODINE" No. 100

"Alodine" No. 100 forms an amorphous phosphate surface on aluminum which is thin, tough, durable, non-metallic, continuous with and a part of the basis metal. The "Alodine" film anchors paint, prolongs paint life, and protects aluminum exposed unpainted to the atmosphere.

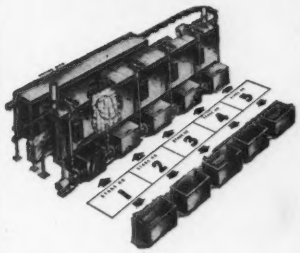
With the "Alodine" No. 100 bath at its normal temperature of 120° F., coating time by immersion approximates 1½ minutes—and by spraying, 15 to 20 seconds. Coating times and bath temperatures can be varied to suit operating conditions.

"ALODINE" No. 600

"Alodine" No. 600 forms corrosion-resistant coatings that provide excellent protection for unpainted aluminum and also make an effective paint-base. This grade is recommended for use in place of "Alodine" No. 100 on aluminum parts that are to remain unpainted or to be only partly painted; and on *all* aluminum castings and forgings whether or not these are given a paint finish.

"ALODINE" FLOW SHEETS

MULTI-STAGE POWER WASHER FOR SPRAY ALODIZING



IMMERSION TANKS FOR DIP ALODIZING

PROCESS SEQUENCE

1. Clean 2. Rinse 3. "Alodine"
4. Rinse 5. Final Rinse

NOTE: Equipment can be of mild steel throughout, except the "Alodine" stage which must be of acid-resistant material.

"Alodine" No. 600 is applied at room temperature (70° to 120° F.). Recommended coating times are 3 to 5 minutes for an immersion process and 1 to 1½ minutes for a spray process.

COATING DATA	"ALODINE" NO. 100	"ALODINE" NO. 600
COMPOSITION	Amorphous phosphate.	Amorphous mixture of metal oxides and chromates.
COLOR	Depending on alloy treated, color range is from an iridescent blue-green to a dark slate gray.	Depending on time of treatment, color range is from golden iridescent to light brown.
THICKNESS	From 0.01 to 0.08 mil. No appreciable dimensional changes occur when aluminum is Alodized.	From 0.005 to 0.01 mil. No appreciable dimensional changes occur when aluminum is Alodized.
WEIGHT	50 to 300 mgs. per square foot. Optimum: 100 to 200 mgs. per square foot.	35 to 50 mgs. per square foot.
SOLUBILITY	Insoluble in water, alcohol, solvents, etc. Insoluble in most dilute acids and alkalis. However, strong acids and alkalis which attack aluminum may penetrate the "Alodine" film and react with the underlying metal. Slightly soluble in concentrated nitric acid. Soluble in molten sodium nitrate, etc.	Insoluble in alcohol, water, solvents, etc. Soluble in strong alkalis and acids.
ELECTRICAL PROPERTIES	High dielectrical resistance.	This coating is electrically conductive. Aluminum coated with "Alodine" No. 600 can be shielded-arc welded or spot welded.
HEAT STABILITY	Unimpaired at temperatures that melt aluminum.	Unimpaired at temperatures that melt aluminum
FLEXIBILITY	Integral with and as flexible as the aluminum itself. Can withstand moderate draws.	Integral with and as flexible as the aluminum itself. Can withstand moderate draws.
ABRASION RESISTANCE	Approximately 90% of that provided by chromic acid anodized aluminum.	Approximately 90% of that provided by chromic acid anodized aluminum.
CORROSION RESISTANCE	Painted—superior to chromic acid anodizing. Unpainted—comparable with chromic acid anodizing. Meets MIL-C-5541 and other Government Finish Specifications.	Exceeds requirements of MIL-C-5541 and even AM-QQ-A-696a (anodic films)
PAINT-BONDING	Excellent. Equal to or superior to anodizing. Meets MIL-C-5541 and other Government Finish Specifications.	Excellent. Meets MIL-C-5541 and other Government Finish Specifications.
TOXICITY	Non-toxic.	Non-toxic.
BIMETALLIC CORROSION RESISTANCE	Shows good resistance against bimetallic or galvanic corrosion.	Shows good resistance against bimetallic or galvanic corrosion.

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "ALODINE" AND ON YOUR OWN ALUMINUM PROTECTION PROBLEMS.

CHEMICALS ACP PROCESSES

New!

GOOD-ALL

NOW AVAILABLE FOR INSTALLATION ON EXISTING GOOD-ALL OR OTHER BRAND OF RECTIFIERS!

FLASHING SIGNAL LIGHT-

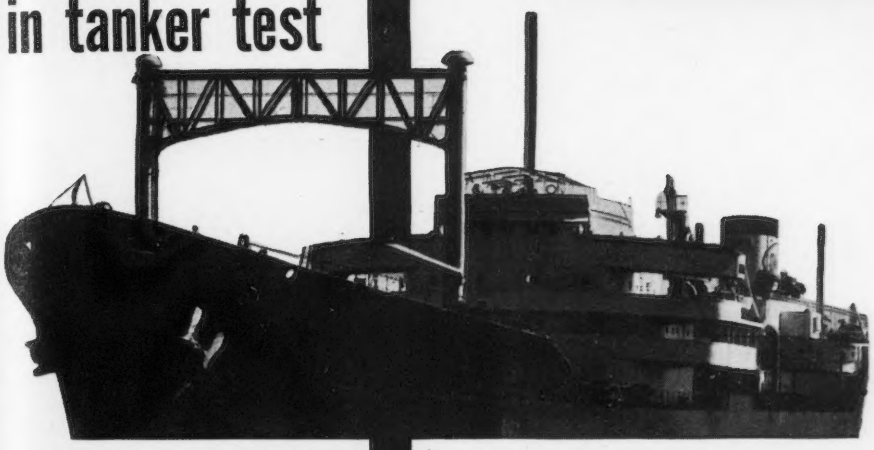
for AIR or AUTO PATROL

Light Can be turned to Face in any direction

- FLASHING LIGHT INDICATES CONTINUOUS CATHODIC CONDITION
- VISIBLE IN DAYLIGHT 300 YARDS OR MORE
- DESIGNED TO INDICATE FAILURE IN EITHER A.C. SUPPLY OR D. C. OUTPUT
- ORDER YOUR NEXT GOOD-ALL CATHODIC PROTECTION RECTIFIERS WITH THIS NEW FLASHING SIGNAL LIGHT

WRITE FOR COMPLETE FACTS TODAY!

SANTOLENE C proves effective in tanker test



Here are the results of a test, started several months ago, to prove the effectiveness of Santolene C in preventing corrosion in a tanker carrying light petroleum products:

How test was made: Strips in two cargo compartments in a tanker were sandblasted clean. Petroleum products carried in these compartments were treated with Santolene C at the rate of 12 lbs./1000 bbls. Two other compartments were cleaned for comparisons. Untreated petroleum products were carried in them. One treated and one untreated test compartment always made the return trip containing salt water ballast.

Here are results: After 8 months, the compartments were inspected. Sandblasted strips in tanks carrying Santolene C had slight, soft scale that could be removed by wiping. Areas not sandblasted had a dull, oily appearance. There was apparently no new scale on these areas and the scale present was clinging tightly to the sides. (This was scale that had been left on the metal when the test started.)

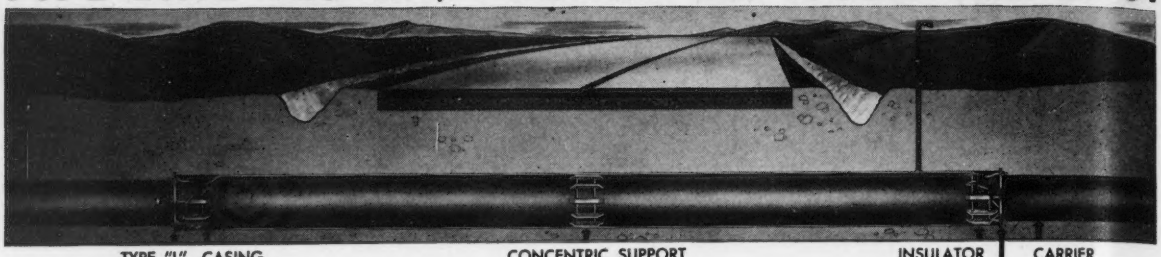
A hard rust-red scale had formed on the sandblasted areas of the compartments without Santolene C. Large sheets of this scale were falling from the sides.

During the period of the test, 153,000 pounds of scale was removed from all compartments of the ship. Scale removed from the two tanks in which Santolene C treated products were carried was 50% to 60% less than that removed from the untreated compartments of the ship.

Santolene C also has proved its effectiveness in actual service by major oil companies. If you have a corrosion problem with transportation or storage of light petroleum products, investigate Monsanto Santolene C. For complete information, write MONSANTO CHEMICAL COMPANY, Organic Chemicals Division, 1700 South Second Street, St. Louis 4, Mo. *Santolene: Reg. U. S. Pat. Off.*

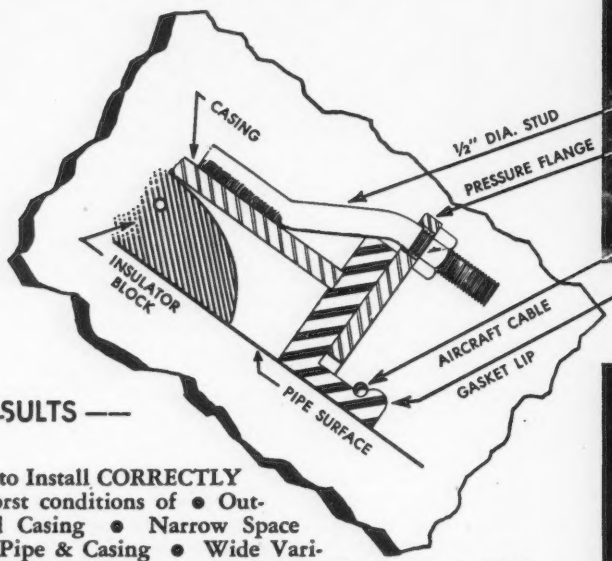
SERVING INDUSTRY . . . WHICH SERVES MANKIND

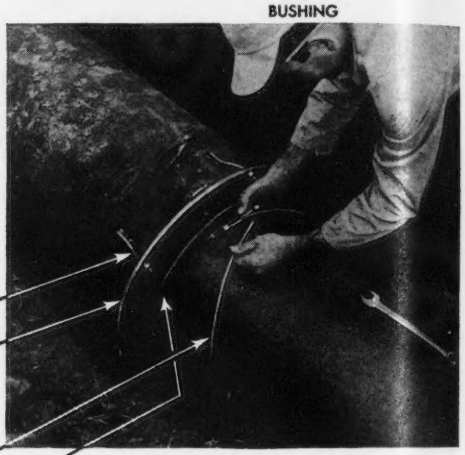
PIPE-LINE TESTED, PROVED and ACCEPTED in '51



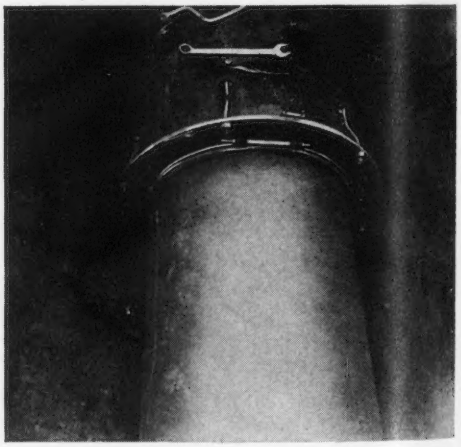
TYPE "L" WmSEAL CASING BUSHING*

A New Design: It BUTTS Against End of Casing Instead of Fitting Inside the Casing.





Assembling cable with rubber-covered union for clamping gasket lip to pipe.



THE COMPLETED INSTALLATION
Note that galvanized cable and union are insulated from pressure flange and from pipe.

RESULTS —

1. Easier to Install CORRECTLY under worst conditions of • Out-Of-Round Casing • Narrow Space Between Pipe & Casing • Wide Variations in Casing Wall and Coating Thickness • Mud • Casing ends beveled — by machine or hand torch.
2. WATER-TIGHT Seal with "L" gasket . . . . . .
   - BUTTED AGAINST CASING as pressure flange is tightened on ½" studs welded to casing.
   - TIGHT TO THE PIPE as aircraft cable (4,600# tensile) is tightened to gasket lip. Union is rubber covered to INSULATE galvanized cable assembly from bare casing structure.
3. Always Insulated from the pipe line when a Concentric-Support Insulator is installed just inside casing after the "drag section" is in place.

AS STRONG & DEPENDABLE AS THE MEN WHO INSTALL THEM

REPRESENTATIVES

Stuart Steel Protection Corp., Kenilworth, N. J. | H. E. Davis, Los Angeles 15, Calif. | James S. Kone Co., Amarillo, Texas | Keyes Tank Co., Provo, Utah | Keyes Tank & Supply Co., Casper, Wyoming | Canadian Equipment Sales & Service Co., Ltd., Edmonton, Calgary, Toronto, Canada

WRITE FOR BULLETIN 249A

T. D. Williamson, Inc.
TULSA 9, OKLAHOMA

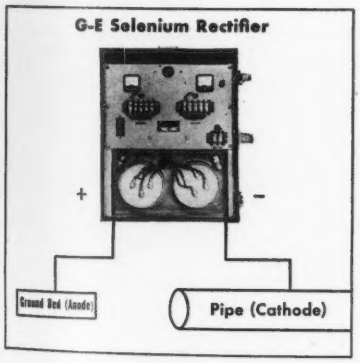
8,000 Pipe Line Casings installed in 1951 with Williamson Bushings and Insulators.

CATHODIC PROTECTION RECTIFIERS

Prevent Costly Pipeline Corrosion

Pipelines—and other underground metal surfaces—are constantly subject to destructive galvanic corrosion.

This condition occurs under all uncontrolled circumstances, depending upon soil conductivity, moisture content, dissolved oxygen content, temperatures, protective coatings, dissimilar metals, position of other metallic structures, stray currents, etc. The way to prevent this costly damage to your underground equipment, is to counteract harmful galvanic action. G-E Cathodic Protection Rectifiers, as part of a properly installed system, will do just that.



HOW IT WORKS

Engineers know corrosion occurs when one metal acts as a cathode, and another as an anode in an electrolyte, such as soil or water. The metal which acts as the anode slowly corrodes, pits, and eventually disintegrates.

The G-E Cathodic Protection Rectifier makes your pipeline the **cathode,** thereby eliminating galvanic actions, as shown in the sketch above.

FAST INSTALLATION

The G-E Cathodic Protection Rectifier is shipped completely assembled. A bracket on the unit permits mounting directly on a pole or wall, and specially constructed foundations are not required. Connectors are designed for rapid installation.

LOW MAINTENANCE

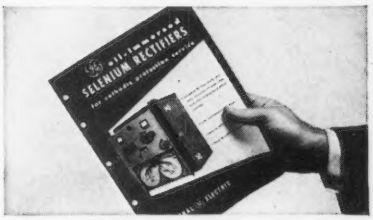
There are no moving parts to wear out in the G-E Cathodic Protection Rectifier. Hermetically sealed, oil-immersed selenium rectifier stacks are long-lived. Oil cannot oxidize or absorb moisture, and never has to be replaced. Access door facilitates meter reading, and inspection of the unit. Two spring clasps retain door, and a hasp is provided for padlocking.

WITHSTANDS SEVERE WEATHER

General Electric's double-walled construction has been developed to withstand extreme variations in weather conditions, most common where cathodic protection is most essential.

INFORMATION AVAILABLE

Because conditions differ in practically every installation, each cathodic protection system should be individually engineered to assure complete protection. For further information on the G-E Cathodic Protection Rectifier or on cathodic protection systems, write today for literature.



Authorized Distributor GENERAL ELECTRIC **Cathodic Protection Rectifiers**

462-8

THE Harco CORPORATION Cathodic Protection Division

OFFICES IN PRINCIPAL CITIES

16991 Broadway, Cleveland, Ohio

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 8 JULY, 1952 No. 7

Technical Practices Committee 19— Corrosion by De-Icing Salts

By F. E. KULMAN, Chairman

Consolidated Edison Co. of New York, Inc.

TECHNICAL PRACTICES COMMITTEE 19 was organized in 1951 to investigate corrosion caused by de-icing salts on metallic equipment above and below the ground surface and to study and recommend mitigation measures. It is composed of representatives of 23 organizations, including suppliers of salt and corrosion inhibitors, automobile manufacturers, utility companies, municipalities and others.

Salt is one of the means used by cities to melt the snow and ice from its traffic thoroughfares. Sizeable amounts of de-icing salts, as much at 3500 to 30,000 tons a year, are being used, depending on the size of the city, its geographical location, climate and other factors. On a per capita basis, the quantity of salt may vary from 7 to 70 pounds per year.

That salt causes corrosion of metallic equipment is well understood. The purpose of the committee is not to examine this fact but to determine quantitatively the severity and extent of this type of corrosion on existing equipment. A superficial survey of the literature shows a wide range of opinion on the effects of the street salts. Many users believe that the corrosive effect is insignificant in the face of an emergency traffic disruption caused by slippery street surfaces. Another group feels that salts are the most important factor in corrosion of automobiles and buried pipes and cables.

Late in 1951 a preliminary questionnaire was sent to the National Association of Corrosion Engineers corporate members and 100 other companies to determine their degree of interest in the de-icing problem. Analysis of the replies showed that 60 companies were concerned with above ground aspects of the problem, while 74 were interested in the effects of the salt on underground equipment. A total of 105 companies desired to receive reports on the subject, 36 wished to contribute their experiences and 23 requested representation on the Committee.

Field investigations over the past eight years have shown the complexity of this problem. Chromate and phosphate inhibitors incorporated in the de-icing salt in concentrations of approximately one percent by weight have not prevented the corrosion to the extent that laboratory alternate immersion testing might lead one to expect. Apparently, significant factors other than salt are involved in the deterioration of the equipment. The field investigations are continuing and the test data will be collected and made the basis for future study by the committee.

At its first meeting, held in conjunction with the Eighth Annual NACE Conference and Exhibition at Galveston, the committee decided to prepare a bibliography of papers and articles on the subject of corrosion by salt. Members of NACE who have had experience with this problem are requested to forward to the committee for incorporation in its bibliography, references on the following topics:

1. Corrosion of automobile bodies.
2. Tests on steel coupons attached to automobiles.
3. Effects of inhibitors in preventing corrosion.
4. Salt as a factor in atmospheric corrosion.
5. Corrosion of underground lead cables.
6. Cathodic corrosion of lead sheathing.
7. Galvanic corrosion in salt solutions.
8. Probable mechanism of corrosion process.

In preparing future field tests, the committee is aware that numerous factors enter into the problem of field testing with coupons. Among these are the amount of snow, number of times the salt is spread, the miles traveled by the test cars, amount of inhibitor used, temperature and humidity of the garage and other factors. In order to get comparable results, it is desirable to arrange tests in three adjacent cities in which controlled conditions of salting, spreading salt with inhibitor and absence of salting

prevail. The committee welcomes inquiries from cities and towns interested in such testing.

A list of members of Committee TP-19 is given below:

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(Quoted from "Guide for the Preparation and Presentation of Papers." National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.)

These instructions and suggestions govern preparation of papers for publication in CORROSION, and for presentation at meetings of the National Association of Corrosion Engineers. Papers may be submitted for consideration without invitation.

Papers submitted are subject to the publication rules and policies of NACE until released, or unless withdrawn by the author prior to presentation or publication. Papers shall not be a rewrite of material presented elsewhere. The same material shall not be rewritten for presentation or printing elsewhere, except that in some cases an article may be rewritten and pointed toward a particular industry without coming under this restriction. After publication in CORROSION, it is the policy of the Association to give permission to reproduce CORROSION articles verbatim. Such permission shall be requested in writing. Full credit must be given NACE as the original source.

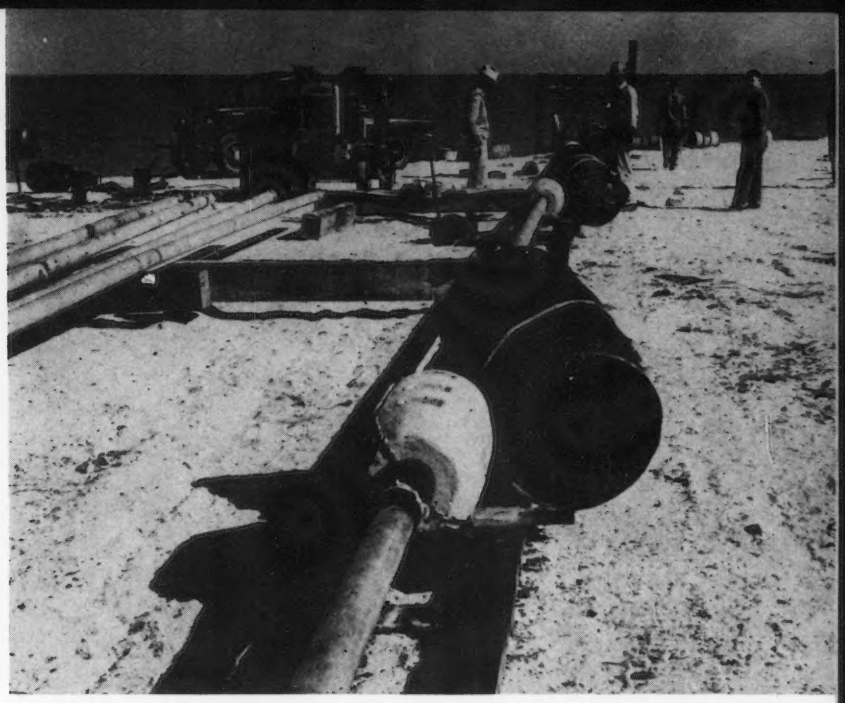


Figure 10—Launching procedure for aluminum line.

Aluminum Alloys for Offshore Pipe Lines*

By EDWARD T. WANDERER and DONALD O. SPROWLS

Introduction

THE NUMBER of offshore oil and gas wells has been rapidly increasing during recent years and transportation of their production imposes severe requirements on pipe lines. To withstand corrosive sea water exposure, conventional steel piping customarily is protected by external coatings (which are not always effective) frequently combined with cathodic protection which requires periodic anode renewal. These protective measures would be minimized if pipe lines of a more corrosion resistant material could be constructed at reasonable cost.

The high resistance to corrosion of many aluminum alloys in marine environments made it desirable to test aluminum pipe in offshore service. This article will report on the construction and subsequent performance of an offshore aluminum pipe line installed in Matagorda Bay, Texas in February, 1950 as part of the gas supply system for the Point Comfort Works of Aluminum Company of America. This plant was built to reduce aluminum oxide to aluminum using electricity generated by 120 gas engine driven generator units. A substantial quantity of the 30,000,000 cubic feet of natural gas required per day for these engines is supplied by offshore gas wells in Matagorda Bay. (Figure 1.) This is gathered at a pressure of approximately 500 psi and is supplied to the plant by an undersea piping system consisting of 10½ miles of 2-inch, 4-inch and 6-inch gathering line and 12½ miles of 8-inch main line. With the exception of the 3500 foot long 4-inch aluminum gathering line, half the length of which is entirely unprotected, all piping is steel, coated and cathodically protected to insure continuous service.

EDWARD T. WANDERER—Head of the Pipe and Pressure Vessels Section of Aluminum Company of America's Sales Development Division, New Kensington, Pa. He holds a BS in mechanical engineering from University of Illinois, 1940. He joined Alcoa at New Kensington upon graduation, became assistant superintendent of the Tube Division in 1943 and in July, 1946 became an engineer in the Sales Development Divison, gaining his present position in 1948. He is a member of American Society of Mechanical Engineers and the National Association of Corrosion Engineers.

DONALD O. SPROWLS—Has been with Aluminum Research Laboratories of Aluminum Company of America since graduation from New Kensington High School in 1936 except for five years attending Drexel Institute of Technology on a cooperative basis. He holds a BS in chemical engineering from Drexel and has done graduate work at Carnegie Institute in metallurgical engineering. Research has been principally in corrosion resistance to natural environments and stress corrosion of aluminum and magnesium base alloys. He is a member of National Association of Corrosion Engineers.

Aluminum Pipe—General Characteristics

Composition

Compositions of standard aluminum pipe alloys

★ A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

Abstract

The rapid increase in offshore oil and gas production has intensified the need for a pipe material that will stand up in coastal waters and marshes. Corrosion problems are severe; steel pipe lines require external protection in the form of protective coatings or cathodic protection or both. Resistance of aluminum alloys to marine exposures led to construction of several welded aluminum marine lines, including one in Matagorda Bay, Texas. This 4-inch welded line, 3500 feet long with one-half entirely unprotected, has been carrying natural gas at about 500 psi pressure for 20 months. After this period of service an inspection showed the exterior and interior surfaces of the pipe were in excellent condition. There was no visible concentration of attack at or adjacent to the welds. Performance confirms corrosion results obtained from samples of 3S, 61S and 63S pipe exposed at this site and sheet samples of the same alloys exposed at other sites. These results give promise an unprotected aluminum alloy pipe line will have long service life under these exposure conditions.

Practical techniques have been developed for construction of aluminum marine pipe lines, including welding, launching and anchoring. Indications are that care must be taken not to overstress welds during launching. While limited experience to date shows bare aluminum lines are approximately equal to coated steel lines in first cost, aluminum pipe lines probably have a cost advantage if maintenance costs for steel are included. Additional corrosion and cost data are needed before definite conclusions can be reached regarding the suitability of aluminum pipe for offshore pipe lines.

and casting alloys that would be considered for marine service are given in Table I. The comparatively new alloy, 63S is similar to the older 61S alloy in composition, both being of the aluminum-magnesium silicide type. It was developed with the object of obtaining an alloy that would have not only a high resistance to corrosion, but also fabricating characteristics that permit its sale at a lower price than 61S. Alloy 63S-T6 is being very widely used for irrigation piping and it is estimated that 14,000 miles of aluminum irrigation pipe are now in use.

TABLE I

Nominal Composition of Some Aluminum Alloys

ALLOY	PER CENT OF ALLOYING ELEMENTS —ALUMINUM AND NORMAL IMPURITIES CONSTITUTE REMAINDER				
	Copper	Silicon	Manganese	Magnesium	Chromium
3S	....	....	1.2	....	....
24S	4.5	....	0.6	1.5	....
43S	....	5.0	....	....	....
53S	....	0.7	....	1.3	0.25
61S	0.25	0.6	....	1.0	0.25
63S	....	0.4	....	0.7	....
B214	....	1.8	....	3.8	....
356	....	7.0	....	0.3	....

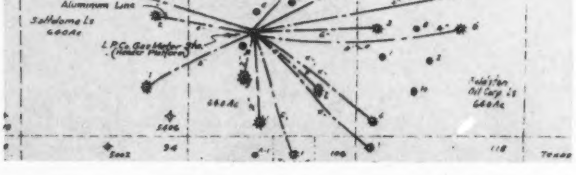


Figure 1—Map of undersea gas lines in Matagorda Bay.

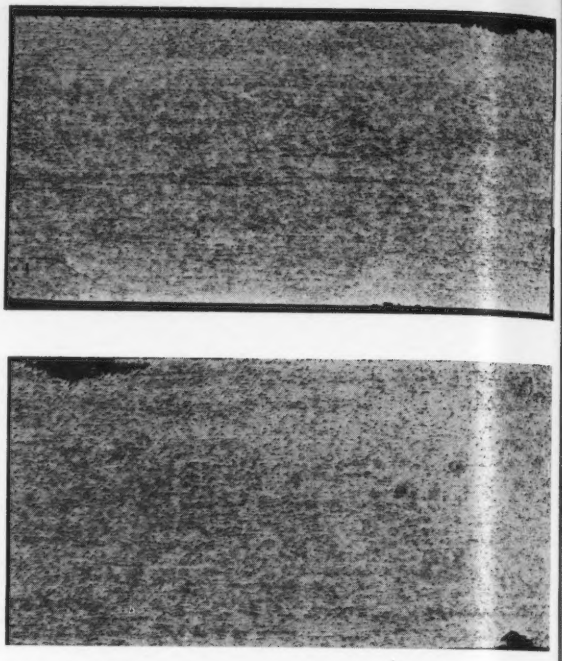


Figure 2—Photomicrographs of transverse sections of ¼-inch thick 61S-T6 plate exposed three years in flowing sea water at Kure Beach, N. C. A 36 inch long panel was exposed half immersed. Corrosion occurred as shallow, localized pits with most of the surface relatively unaffected. Depth of attack measurements are shown. Magnification about 10X. Top—Water line area 2.1 mils avg., 7.0 mils max. Bottom—Total immersion 0.5 mils avg., 14.0 mils max.

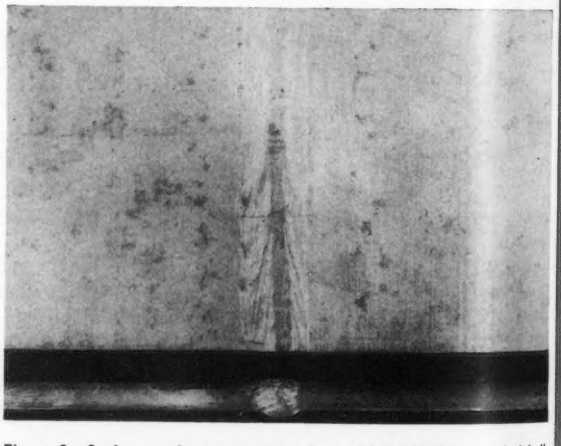


Figure 3—Surface and cross section of a welded 61S-T6 extruded bulk section 3/16-inch thick exposed two years to tidewater at Miami, Fla. Weld was made by automatic carbon arc process using 43S alloy filler wire. Both extruded sections and 43 alloy welds are in excellent condition showing only superficial pitting of extruded sections too shallow to be noticed in cross-section. Magnification about 1X.

Strength

Table II shows typical tensile properties of the standard pipe alloys and of some casting alloys. A comprehensive test program carried out by Alcoa indicated that the bursting pressure for circumferentially welded 63S-T6 Schedule 40 pipe of nominal wall thickness was approximately 2600 psi. Thus, if control failure occurred and the full 1800 psi well head pressure were introduced into the pipe line, failure would not be expected.

The test program also indicated that bending strength of welded pipe joints would be sufficient to resist the beam action which occurs as the pipe is being lowered in place.

Resistance to Corrosion

Corrosion tests and actual service experience over a period of many years have demonstrated the high resistance to corrosion of 61S alloy in marine environments. (Figures 2 and 3.) Included in the ever increasing list of marine applications of aluminum alloys are: boat hulls, submarine fairwaters and radar masts, lifeboats and davits, deckhouses and superstructures. Information concerning the performance of aluminum alloys in marine environments has been published elsewhere[1,2] and need not be considered in detail here.

Corrosion data for the older alloy, 61S are naturally more complete than those for the newer alloy, 63S. Sufficient data are available, however, to show that the resistance to corrosion of 63S alloy products in marine environments is at least as high as that of 61S alloy products. The high resistance of these alloys to attack by sea water is shown by the excellent condition of extruded shapes of 63S-T5 and 61S-T6 which have been exposed to tidewater at Miami, Florida for a period of one year. (Figure 4.) The resistance of these alloys to saline conditions is further demonstrated by another investigation in which round tension specimens were machined from rod or bar of 63S-T5, 61S-T6, and 3S-H18 and exposed from 12 to 14 months to a 3½ percent sodium chloride solution by alternate immersion. The losses in tensile properties caused by corrosion (Table III) were small in all cases, although slightly less for alloys 63S-T5 and 3S-H18 than for 61S-T6.

Although the inherent resistance to corrosion of these alloys is good, attack can occur as a result of contact with some dissimilar metals or contact with a water absorptive non-metallic material such as wood. Dissimilar metal contact is a particularly important consideration in the case of an aluminum alloy marine pipe line because in sea water aluminum alloys are anodic to other common metals such as steel and copper-base alloys. It is imperative, therefore, that proper precautions be taken where components of aluminum alloys and cathodic metals must be connected. Considerable literature is available on the subject of electrochemical corrosion and designing to prevent it.[3,4,5]

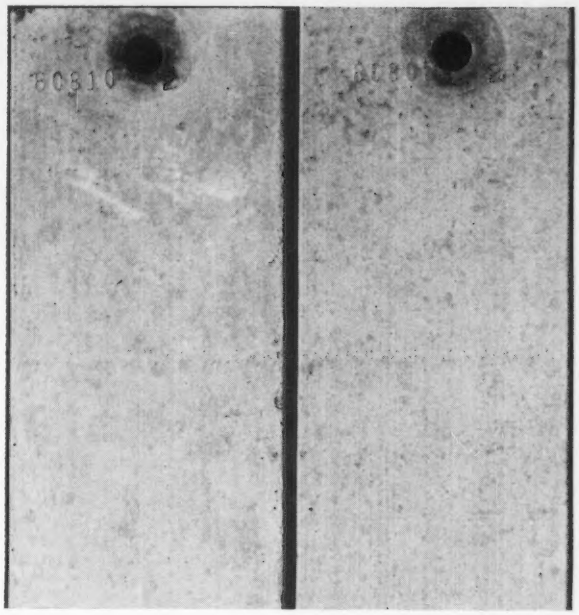
Fluid Flow

The surface characteristics of aluminum pipe warrant the use of friction factors for "smooth" pipe. This is of particular importance in gas transmission service where pumping is required, since head losses would be kept at a minimum. No loss in the original efficiency should develop with continued use, because gas service should cause no appreciable surface roughening.

Corrosion Test Program—Aluminum Pipe Samples

Matagorda Bay—4-Inch Pipe

To supplement data to be provided by the alumi-



63S-T5 61S-T6

Extruded ¼-inch x 2-inch bars exposed one year to sea water by tidewater immersion at Miami, Fla.

Figure 4—These samples showed only superficial corrosion. Microscopic examination revealed a few very small localized pits with maximum depths of 2.4 mils for 63S-T5 and 5.6 mils for 61S-T6. Specimens were chemically cleaned. Magnification about 1X.

TABLE II

Typical Tensile Properties of Some Aluminum Alloys

Alloy and Temper	Tensile Strength p.s.i.	Yield Strength (Offset=0.2 Percent) p.s.i.	Elongation, Percent in 2" (½" Diameter Round Specimens)
3S-F	17,000	8,000	40
24S-T4	68,000	48,000	19
53S-T6	37,000	32,000	13
61S-T6	45,000	40,000	17
63S-T6	35,000	31,000	12
B214*	20,000	13,000	2.0
356-T6*	33,000	24,000	3.5

* Sand Cast.

TABLE III

Per Cent Changes in Tensile Properties of Machined Tension Specimens of Aluminum Alloys Exposed to 3½% Sodium Chloride Solution by Alternate Immersion

Alloy	Product	SPECIMEN TESTED Direction	Size, Dia.	Exposure Period Months	Percent Change By Corrosion T.S.	EL.
	⅝" Dia.					
63S-T5	Extruded Rod	Longitudinal	7/16"	14	+ 3	—11
61S-T6	Rolled Rod	Longitudinal	7/16"	14	— 3	—10
3S-H18	Rolled Rod	Longitudinal	7/16"	14	— 1	+ 1
	¼" x 2"					
63S-T5	Extruded Bar	Longitudinal	⅛"	12	— 1	—33
63S-T5	Extruded Bar	Transverse	⅛"	12	0	—12
61S-T6	Extruded Bar	Longitudinal	⅛"	12	— 5	—35
61S-T6	Extruded Bar	Transverse	⅛"	12	— 8	—59
61S-T6	Rolled Bar	Longitudinal	⅛"	12	— 1	—50
61S-T6	Rolled Bar	Transverse	⅛"	12	— 5	—56

Notes: 1. All specimens tested in duplicate; average values given.

2. Alternate immersion cycle (1 hour); 10 minutes immersion, 50 minutes drying time in air at R. T.

Figure 5—Shows the extent of marine fouling on immersed portion of pipe specimen and rack during 15 months' exposure in Matagorda Bay. Specimens shown, left to right are: bare steel, coated 3S-F, bare 63-T5. Insulated wire leads were attached to each pipe so electrode potentials of pipes could be measured in sea water.

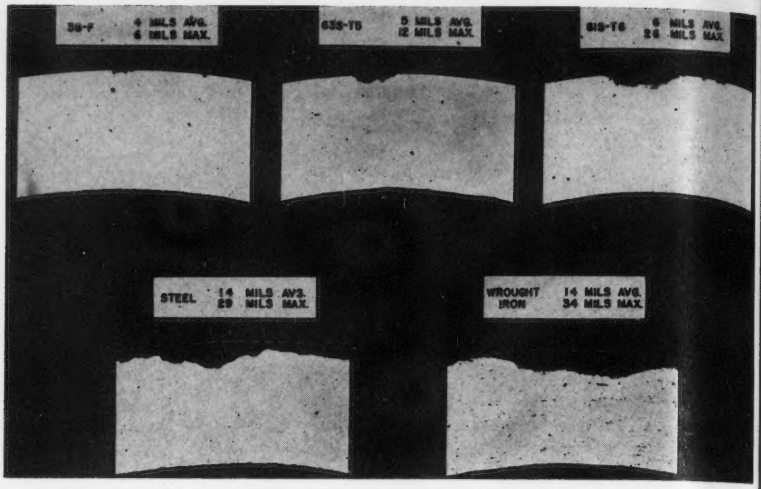

3S-F 4 MILS AVG. 6 MILS MAX.
63S-T5 5 MILS AVG. 12 MILS MAX.
61S-T6 6 MILS AVG. 26 MILS MAX.
STEEL 14 MILS AVG. 29 MILS MAX.
WROUGHT IRON 14 MILS AVG. 34 MILS MAX.

Figure 6—Photomicrographs of transverse sections of 1¼-inch diameter pipe specimens totally immersed 15 months in Matagorda Bay. Only exterior (top) surfaces were exposed to sea water. The broken white lines were drawn on photomicrographs of ferrous samples to indicate original surface of pipes. Original surface of aluminum alloy specimens is evident because no general attack or thinning of pipe walls occurred. Results of depth of attack measurements of these pipes are given. Magnification about 10X.

num pipeline, a specimen of 4-inch 63S-T6 pipe was placed on the bottom of Matagorda Bay at the header platform. After 18 months' exposure, only discoloration was found where it had been in contact with the mud bottom. Likewise, no significant corrosion was found when the marine growth was scraped from the surface which was not contacting the mud.

Matagorda Bay—1¼-Inch Pipe

Concurrently with the 4-inch pipe just described, a more comprehensive test program was started. Samples of 1¼-inch pipe were exposed on special aluminum racks that were attached to pilings underneath the header platform in Matagorda Bay. The 5 foot long samples were exposed vertically so half their length was continuously immersed and half exposed to the atmosphere. Among the various pipe materials included were aluminum alloys 63S-T5, 61S-T6, 3S-F, wrought iron and black steel. Ends of the aluminum pipes were closed with standard cast B214 alloy pipe caps and the ends of the ferrous alloy pipes were closed with cast iron pipe caps. Figure 5 shows a rack containing some of the pipe specimens after 15 months' exposure in Matagorda Bay.

An examination of the pipe specimens after the 15-month exposure showed only very slight corrosion in the form of scattered minute pits on the aluminum alloy pipes compared with the considerable rusting and pitting of the ferrous specimens. Micrographs of cross sections of these pipes and depth of attack measurements are shown in Figure 6. The aluminum pipe caps were also in excellent condition. An anti-seize compound (Army-Navy Aeronautical Specification AN-C-53, Amendment 1, Superseded by Spec. JAN-A-669) had been used in the original assembly of the threaded joints and all caps were readily unscrewed at the time of the inspection. The welded 61S-T6 exposure racks were also in very good condition, there being some scattered pitting but no indication of selective attack of the welds or in the vicinity of the welds. (Figure 7.)

Miami, Florida Tidewater—1¼-Inch and 6-Inch Pipe

A duplicate series of 1¼-inch pipe specimens is being exposed to the sea water at Miami, Florida. These specimens were placed horizontally at a level where they are totally immersed at high tide. Also exposed were two 16-inch long samples of 6-inch 63S-T6 pipe, one containing a circumferential butt weld made by the inert gas metal arc process (argon tungsten) employing 43S alloy filler wire. No pitting of any of the aluminum alloy specimens was observed when they were inspected after an exposure of six months, although there was considerable scaling of the ferrous materials.

Aluminum Pipe Line In Matagorda Bay, Texas

The aluminum pipe line laid in Matagorda Bay at an average depth of 12 feet[6] extends approximately 3500 feet underwater from one of the offshore wells (Well No. 2, State Tract No. 95, Matagorda Bay, Calhoun County, Port Lavaca, Texas) to the header platform. (Figures 8 and 9.)

Materials

The line was built of 4-inch Schedule 40 63S-T6 aluminum pipe supplied in 40-foot lengths and mill

beveled. Flanges were of the raised face 600-pound welding neck type made from forged aluminum alloys 53S-T6 and 61S-T6. Studs, nuts and washers of Alumilite-finished 24S-T4 alloy were used in making up aluminum-to-aluminum flanged joints. Galvanized steel bolts with insulating sleeves, washers and gaskets were used for aluminum to steel flanged joints. Insulation was provided to prevent galvanic action between the aluminum pipe and the mating steel pipe and it also serves to prevent stray current flow from the cathodically protected steel pipe. The aluminum line was separated into two electrically isolated sections by the insulating joint between the bare and coated lengths. Subsequent electrical measurements indicated the insulation system was effective. On each end of the aluminum line was installed a 6-inch 1,000 psi swivel joint of casting alloy 356-T6 connected to the 4-inch line by 6-inch to 4-inch reducers of 61S-T6 alloy.

Construction

Aluminum welds were made with 43S filler wire by the inert gas metal arc process (argon tungsten). This process permits welding in all positions, but rolling welds were made in practically all cases because of the greater speed. Time for individual welds averaged seven minutes.

Sections 400 feet long were welded together and no leaks or other evidence of unsatisfactory welds were found under 1000 psi hydrostatic pressure. Each welded joint was then coated, wrapped and a 441-pound concrete river weight was attached over the weld, resulting in a negative buoyancy of 3 pounds per foot.

A section 1600 feet long was constructed of pipe that had been mill wrapped and coated with a primer, two coats of pipe line enamel, one wrap of borosilicate glass fiber tape and a final wrap of Kraft paper. Welded joints were field wrapped and coated using the same system. The 1900-foot section was unprotected except for areas under the river weights. A 40-foot length with flanges was incorporated in each of the two sections of the line to facilitate inspection.

Preparatory to launching the pipe (Figure 10), a 400-foot section was placed on skids on a lubricated runway and pontoons were attached at the weights. After the flanged end was plugged, the pipe was towed off by boat, with additional 400-foot sections being welded into the line until the desired length was attained. The unprotected section was towed to the well and the coated section to the header platform; both were lowered in place by cutting free the pontoons. Necessary welding for completing the tie-in was carried out on a barge.

Construction of the line was completed February 23, 1950 but it was not placed immediately in service. When gas was finally introduced into the line, two welds were found to require repair, apparently as a result of overstressing during launching. The repairs were completed on a barge and the line was finally placed in service May 17, 1950.

Inspection

In July, 1951, a leak was encountered at the well

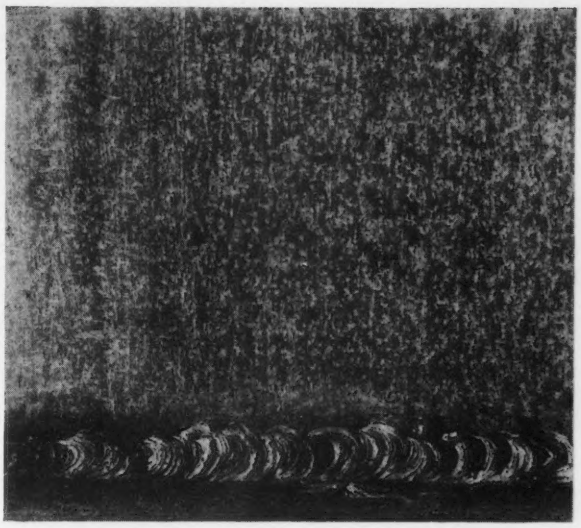


Figure 7—Good condition after 15 months' exposure in Matagorda Bay of welded joints in 61S-T6 exposure racks for pipe specimens is shown. Welds were made by the inert gas metal arc process (argon tungsten) using 43S alloy filler wire. This weld was exposed just a few inches above the mean water level. The surface has been cleaned after exposure. Scattered small pits may be observed in the rolled 61S-T6 channel. Magnification about 1X.

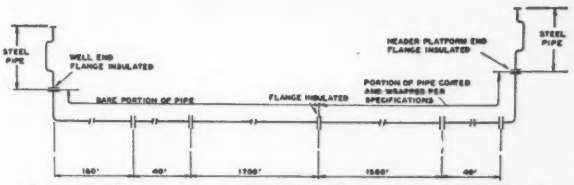


Figure 8—General layout of pipe line (Approximately 3500 feet).

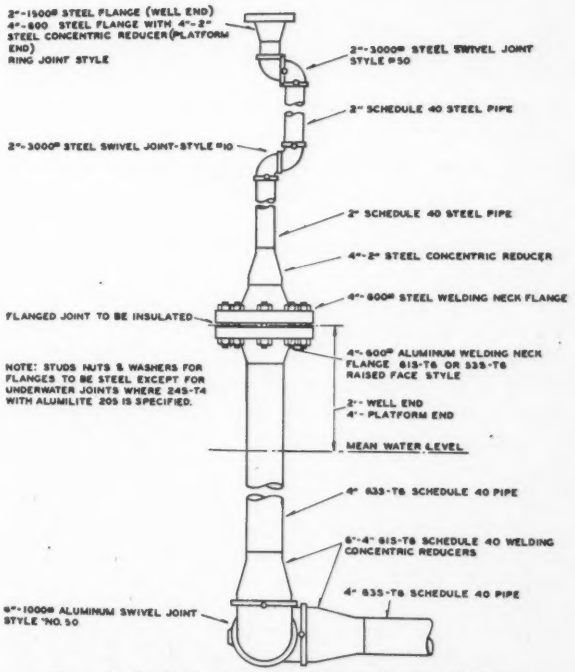

2"-1500# STEEL FLANGE (WELL END)
4"-600 STEEL FLANGE WITH 4"-2" STEEL CONCENTRIC REDUCER (PLATFORM END)
RING JOINT STYLE
2"-3000# STEEL SWIVEL JOINT STYLE #50
2" SCHEDULE 40 STEEL PIPE
2"-3000# STEEL SWIVEL JOINT-STYLE #10
2" SCHEDULE 40 STEEL PIPE
4"-2" STEEL CONCENTRIC REDUCER
4"-600# STEEL WELDING NECK FLANGE
FLANGED JOINT TO BE INSULATED
4"-600# ALUMINUM WELDING NECK FLANGE 61S-T6 OR 52S-T6 RAISED FACE STYLE
NOTE: STUDS NUTS & WASHERS FOR FLANGES TO BE STEEL EXCEPT FOR UNDERWATER JOINTS WHERE 24S-T4 WITH ALUMILITE 205 IS SPECIFIED.
2'-WELL END
4'-PLATFORM END
MEAN WATER LEVEL
4" 52S-T6 SCHEDULE 40 PIPE
6"-4" 61S-T6 SCHEDULE 40 WELDING CONCENTRIC REDUCERS
4" 52S-T6 SCHEDULE 40 PIPE
6"-1000# ALUMINUM SWIVEL JOINT STYLE "NO. 50

Figure 9—Detail of risers at well head and header platform.

Figure 11—Riser at well end of aluminum line. Marine growth removed from one area.

Figure 12—Swivel joint area. Marine growth removed at weld.

Figure 13—Construction of aluminum pipe line in South Louisiana marsh.

(unprotected) end of the line and upon investigation, it was found the swivel joint gaskets required replacement. No apparent attack on the aluminum was found during a superficial inspection made at this time.

In October, 1951, after 20 months' immersion in the bay, the riser at the well, together with about 10 feet of line, was raised to permit a thorough inspection of the unprotected aluminum. (Figures 11 and 12.) Marine growth that completely covered the aluminum was scraped away at a number of locations; inspection revealed no indication of significant corrosion of the piping and the welds. The flange and portion of the riser above the water line were stained with rust from the steel above the joint, but no appreciable attack of the aluminum was observed here or at the water line. Some cratering was noted on each end of the center section of the cast swivel joint, but it was impossible to establish whether this resulted from corrosion or mechanical causes. Electrical potential and current measurements made during this inspection ruled out long-line currents as a cause of corrosion.

The interior of the riser at the flange was found to be in good condition.

Aluminum Pipe Line—South Louisiana Marsh

It has been reported that the welded 63S-T6 aluminum crude oil pipe line laid without protection in South Louisiana shows no evidence of external corrosion after 3½ years of service[7] whereas unprotected steel pipe laid in this area develops leaks in two years and requires replacement in five years. The aluminum line was laid in May, 1948, on the bank of the Intracoastal Canal, buried in ground slightly higher than the surrounding marsh. No corrosion had been discovered up to July, 1950, at which time the line was moved to a location nearby where most of it is submerged in the salty water. (Figure 13.)

Economic Considerations

Where construction is relatively difficult and expensive as in the case of pipe lines laid in marshy or offshore sites, the light weight, smooth surface and ease of handling of aluminum pipe result in appreciable economies in construction costs. Actual experience has proved these economies tend to offset the higher material cost of aluminum pipe compared to steel pipe.[8,9] Even in reasonably smooth terrain the installed cost premium for aluminum pipe lines has not exceeded 30 percent.

The Matagorda Bay installation did not provide an exact basis on which to compare the cost of an unprotected conventional aluminum line to that of a coated and cathodically protected steel line. There were many extra-cost experimental features of the aluminum line, including flanges for the inspection sections and for the center insulation, the experimental coating job and the necessity of using oversize swivel joints with reducers because of availability. Also, the aluminum welding was not included in the contractor's cost. It can reasonably be assumed, however, that the cost of welding would not exceed the cost of the extra flanges, etc., and since the contractor's actual aluminum line cost and estimated steel line cost were approximately equal, this relationship should hold true for conventional aluminum and steel lines. Assuming long life for the aluminum line, later economies would result because anode replacement costs would not be incurred.

Conclusions

An aluminum offshore natural gas gathering line was successfully constructed in Matagorda Bay, Texas in February, 1950, and after 20 months' immersion in sea water, corrosion of the unprotected aluminum alloys was found to be negligible. Favorable results have also been experienced with an unprotected aluminum crude oil gathering line that has been in service for 42 months in a brackish marsh in south Louisiana. These results give promise that

aluminum alloy pipe lines will have a long service life under these adverse conditions.

In addition to its high resistance to corrosion, aluminum pipe is light in weight and easy to handle, and its smooth surface reduces friction losses in transmitting fluids. Cathodic protection being unnecessary, initial and replacement costs of anodes are eliminated. Some additional care must be taken in handling during launching, however, and heavier anchorage is required than for steel.

By the use of established techniques which can be learned easily by an average construction crew, unprotected aluminum offshore pipe lines can be constructed at a cost comparable to that of coated and cathodically protected steel pipe lines. Current expansion of aluminum production capacity should also assure availability of the metal in the future.

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By WILLARD R. SCOTT and GILSON H. ROHRBACK*

Abstract

A method of inhibitor evaluation based on measurement of hydrogen evolved during corrosion, apparatus used, evaluation procedure and typical test results are given. The method was developed to simulate oil well corrosion as closely as possible and still give rapid evaluation results. Hot brine is passed continuously by an iron coupon and subsequently discharged from the system to prevent build-up of corrosion products. Simulation of fluid flow is accomplished by rotating the sample and provision is made for introduction of a gas in the brine. The gas and liquid leaving the iron coupon are separated and the amount of hydrogen in the gas stream determined. This provides a means of continuously measuring the rate of hydrogen evolution and consequently of the corrosion rate. Effect of a chemical on this rate is determined by injecting it into the flow stream in front of the sample and recording the change in rate of hydrogen evolution. Oil is not used in the liquid stream because oil well corrosion is an ionic process and occurs only when metal is in contact with water.

Introduction

ONE OF THE MOST promising methods for control of oil well corrosion is the use of inhibitor chemicals in downhole injection. Field tests with chemicals such as sodium dichromate have established that well maintenance costs can be reduced substantially by suitable inhibitor treatment. More effective inhibitors are needed, however, and considerable research is in progress on their development.

A large number of substances are reported in the literature to be corrosion inhibitors. In fact, almost every class of organic and inorganic chemical has been listed as a possible inhibitor under specific conditions. The wide diversity of results with the same chemical under different corrosion conditions shows that inhibitor action is highly specific, and substances effective in controlling one type of corrosion are not necessarily effective in controlling a different type. In particular, much of the previous evaluation data cannot be applied to oil well corrosion, which takes place in weakly acidic solutions and in the absence of oxygen. Rapid and reliable methods are needed, therefore, to classify the large number of compounds that might be useful as corrosion inhibitors in oil wells.

Oil well corrosion is known to occur by an electrochemical reaction in which iron dissolves at anode points to give ferrous ions and hydrogen ions deposit at cathode points to give hydrogen gas. This process may be represented by the over-all equation

$$Fe + 2H^+ \rightarrow Fe^{++} + H_2,$$

where hydrogen ions are furnished by dissociation of carbonic acid, of organic acids, and in many wells, of hydrogen sulfide.

In order to follow the reaction above, it is necessary to measure either the disappearance of one of the reactants or the appearance of one of the products. Four general methods are thus available for determination of corrosion rates and for determination of effectiveness of different substances as inhibitors:

1) Measurement of hydrogen ion consumed.
2) Measurement of iron consumed.
3) Measurement of Fe^{++} produced.
4) Measurement of H_2 produced.

In the highly buffered solutions common to oil wells, measurement of the amount of hydrogen ion consumed is not feasible and therefore only three methods can be used for inhibitor evaluation. These three methods supplement each other as research tools. Studies that cannot be made readily by one method usually can be made by another.

This article presents a method of inhibitor evaluation based on the measurement of hydrogen evolved during corrosion. An apparatus is described which gives a continuous record of the corrosion rate. Evaluation procedure and typical test results are given. Results are reported only for tests in which carbonic acid was used as the source of hydrogen ions.

Method

The hydrogen evolution method previously has been applied mainly to static systems containing strong acids and relatively high inhibitor concentrations. In such systems, accumulation of corrosion products and polarization of the metal surface can decrease the corrosion rate markedly even when no inhibitor is present. Such conditions are greatly different from those that exist in producing oil wells where only weak acids are present and corrosive liquid is constantly renewed.

In the work reported here, the hydrogen evolution method was adapted to simulate oil well corrosion as closely as possible and still give rapid evaluation results. Hot brine was passed continuously by an iron coupon and subsequently discharged from the system to prevent build-up of corrosion products. Simulation of fluid flow was accomplished by rotating the sample and provision was made for introduction

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The method does not use oil in the liquid stream. Advantages of omitting oil in this particular method far outweigh the objection that well conditions are not completely duplicated. Oil well corrosion is an ionic process and occurs only when the metal is in contact with water. Oil in the liquid would displace some of the water from the metal surface and would decrease the overall amount, but not the specific rate of corrosion.

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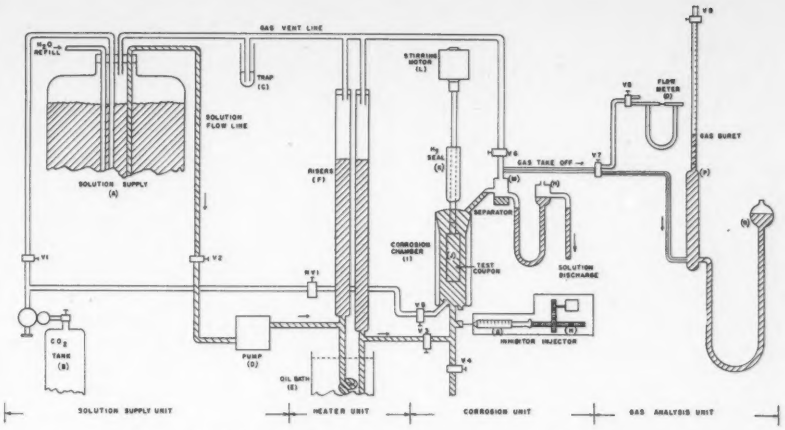

Figure 1—Schematic diagram of hydrogen evolution apparatus.

Apparatus

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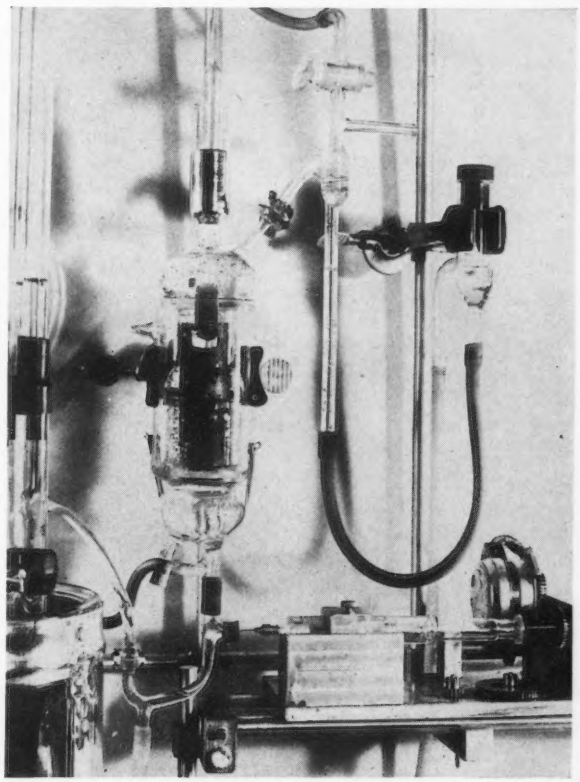

Figure 2—Corrosion unit, showing injector, corrosion chamber and liquid-gas separator.

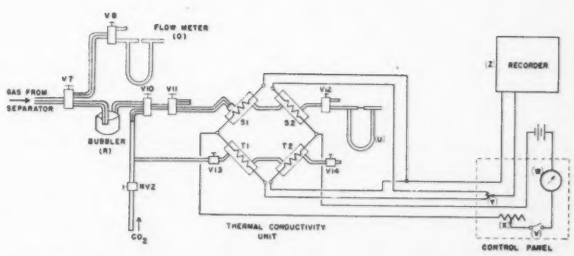

Figure 3—Arrangement of thermal conductivity cells for gas analysis.

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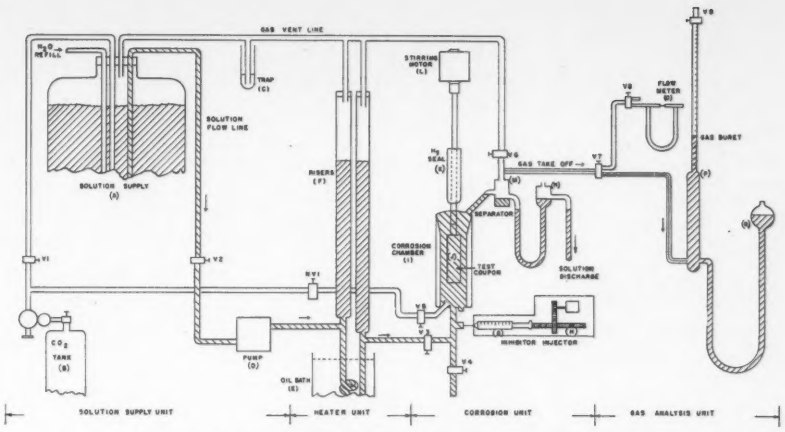

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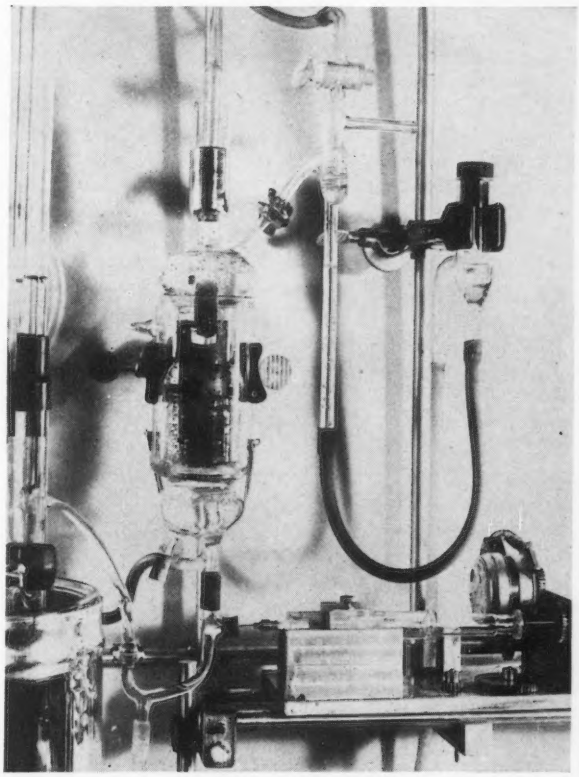

Figure 2—Corrosion unit, showing injector, corrosion chamber and liquid-gas separator.

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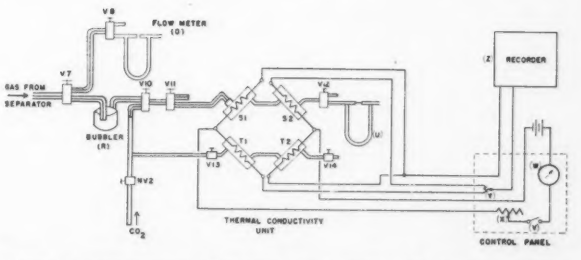

Figure 3—Arrangement of thermal conductivity cells for gas analysis.

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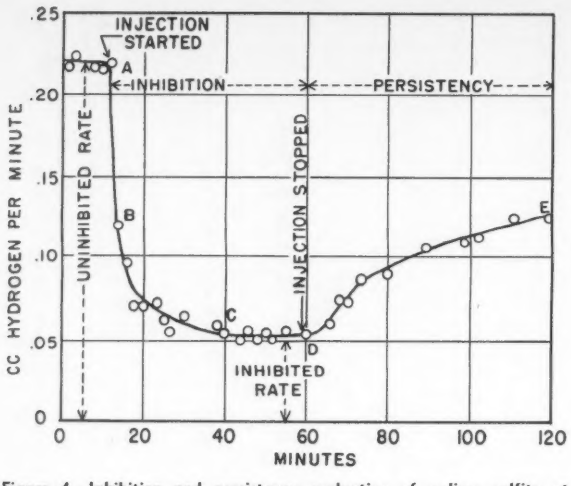

Figure 4—Inhibition and persistency evaluation of sodium sulfite at 100 ppm. and 165 degrees F.

for carbon dioxide. The carbon dioxide inlet terminated in a sintered glass disc near the bottom of the chamber. A third opening in the chamber was provided so that the solution could be connected to a reference electrode.

The top of the chamber was fitted with a thermometer well, a mercury-seal stirring well and an outlet tube. These parts were made as a single unit to avoid connections through which hydrogen might be lost.

Iron coupons used in the apparatus were 3½ inch lengths cut from 1-inch SAE 1015 steel tubing. They were slotted at one end to fit on the glass T-support of the stirring rod. When the electrode potential of the coupon was to be followed, the coupon was attached directly to an iron stirring rod and electrical contact was maintained through the mercury seal.

The inhibitor injector device was a standard 10 ml hypodermic syringe (G). The plunger of the syringe was driven at a constant rate by a synchronous clock motor (H). The rate of advance of the plunger could be changed by changing the gear ratio between the motor and a traveling screw.

Effluent from the corrosion chamber discharged into the gas-liquid separator (M). The inlet and liquid outlet of the separator bulb were arranged so that liquid and gas were retained long enough to give complete separation. Liquid from the separator was discharged from the system through the U-tube trap and leveling bulb (N) to the drain. This method of discharge permitted effective separation of gas from the liquid over a wide range of gas-liquid flow ratios and also prevented air entry to the gas analyzer. The leveling bulb was open to the atmosphere to prevent a siphoning action.

The gas leaving the separator usually contained only carbon dioxide, hydrogen and water vapor. If the corrosive solution contained acetic acid or if a volatile inhibitor was tested, traces of these would be present also. This gas was conducted by capillary tubing to the gas analyzer where the amount of hydrogen was measured.

Two methods were used for measurement of the hydrogen evolved by corrosion. The first method used the apparatus (P, Q) shown in Figure 1. In this apparatus, carbon dioxide in the gas mixture was removed by bubbling the gas through concentrated potassium hydroxide solution and collecting the hydrogen remaining in the graduated portion of the gas buret (P). The two-way stopcock (V7) permitted gas from the separator to be directed into either the buret (P) or gas flow meter (O).

The second and more convenient method of gas analysis utilized four thermal conductivity cells, connected to form a Wheatstone bridge, and an associated recording device. Arrangement of the thermal conductivity unit is shown schematically in Figure 3. During an evaluation run, gas from the separator was passed through cells (S1) and (S2), while carbon dioxide from the supply tank was passed through cells (T1) and (T2). This arrangement compensated for any change in the impurity content of the carbon dioxide supply inasmuch as the conductivity due to impurities would change approximately the same amount on each side of the bridge. Valves (V10) to (V14) allowed the cells and connecting tubes to be flushed. The bubbler (R) contained concentrated sulfuric acid and was included to remove water vapor from the gas stream.

Electrical leads from the cells were brought to a control panel, shown by dotted lines in Figure 3. The panel was made up of cell energizing switch (V), current meter (W), and variable resistors (X) and (Y). The recorder (Z) was connected to the output of the bridge circuit as shown.

Evaluation Procedure

The liquid used for these corrosion studies was a three percent solution of sodium chloride in tap water, and was saturated with carbon dioxide. Carbon dioxide was bubbled through the solution for at least one hour to insure saturation and to remove dissolved air. The solution was heated to a temperature of about 150 degrees F by passage through the oil bath. At this temperature, corrosive properties of the solution were similar to those of brine in producing oil wells.

Coupon surfaces were prepared by successively acid etching, rinsing with water and sand blasting. This preparation was the only one of several tried that gave a satisfactorily constant corrosion rate for an uninhibited coupon. Several coupons were prepared at one time and stored in a desiccator. Coupons were cleaned with carbon tetrachloride to remove any grease film just before they were used in an evaluation run.

At the start of a run, a cleaned coupon was placed in the corrosion chamber through the ground glass joint, valves (V7) and (V8) were opened to the atmosphere, and pump (D) was started. After solution had displaced air from the chamber, the chamber and gas flow line as far as (V7) were flushed for several minutes with a rapid stream of carbon dioxide. The carbon dioxide input then was readjusted by means of needle valve (NV1) so that the total gas output reached the desired level, as indicated by flow meter (O).

After about 10 minutes, the rate of hydrogen evo-

lution was usually constant (0.2 to 0.3 cc a minute), and injection of inhibitor solution was begun. The desired concentration of inhibitor in the chamber was produced by proper selection of injection rate and inhibitor concentration in the syringe. The injector was normally operated so that a 10 cc syringe was emptied in approximately one hour, but the injection rate could be changed to either twice or one-half the normal value by changing gears. At the normal injection rate, a concentration of 0.14 grams of inhibitor in 10 ml of solution was used to give 50 ppm in the chamber.

When the inhibitor was not water soluble, organic solvents miscible with water and having boiling points above 200 degrees F were used. Dioxane and carbitols were useful for this purpose. Lower boiling solvents were not suitable because they vaporized in the hot solution and often caused the inhibitor to precipitate without dispersing.

The most efficient absorption of carbon dioxide from the gas was obtained by use of a 50 percent aqueous solution of potassium hydroxide in the buret. This solution was considered spent when the bubbles required more than six inches of travel through the solution to attain minimum size. Commercially available carbon dioxide contained enough impurities insoluble in 50 percent potassium hydroxide solution to give an appreciable quantity of unadsorbed gas. This background rate was subtracted from the total collection rate observed during a run in order to obtain the true hydrogen evolution rate. The background was obtained by making a run with no coupon in the corrosion chamber. The percent impurities in a tank of carbon dioxide changed as gas was used, and therefore the background correction was determined from time to time. The observed average for several tanks of USP carbon dioxide was 0.08 percent unadsorbed gas.

Use of the thermal conductivity bridge in place of the gas buret involved several modifications of the analysis procedure. An outline of steps after a coupon had been placed in the chamber is given below:

1. Valves (V7) and (V8) were opened to the atmosphere and the chamber and gas flow lines were flushed. Gas flow was adjusted to give the desired rate in flow meter (O). The cells of bridge were then flushed with carbon dioxide from supply tank (B).

2. Valve (V12) was turned to flow meter (U). Gas flow from the supply tank was adjusted by means of needle valve (NV2) to give the same flow rate through cells (S1) and (S2) as that from the corrosion chamber as shown by flow meter (O).

3. The bridge was energized by closing switch (V) and resistance (X) was adjusted for proper bridge current as indicated on ammeter (W). Slide wire (Y) was adjusted to give zero reading on the recorder.

4. Valves (V7), (V10), and (V11) were turned so that gas from the corrosion chamber entered cells (S1) and (S2).

5. When the recorder showed constant reading, injection of inhibitor was started. Values of recorder readings were changed to percent inhibition by means of a calibration curve for known mixtures of hydrogen and carbon dioxide.

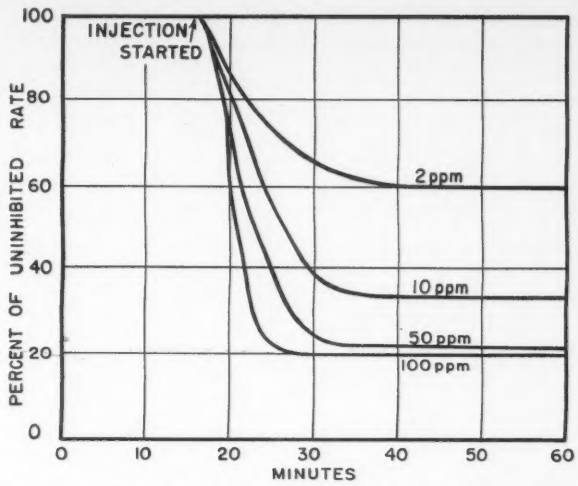

Figure 5—Evaluation of sodium sulfite at 165 degrees F by multiple coupon method.

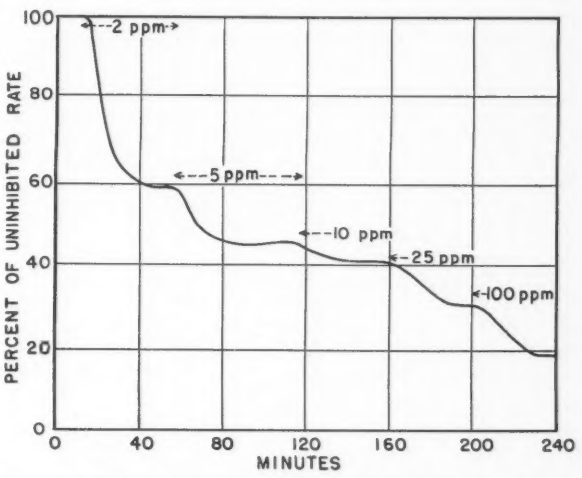

Figure 6—Evaluation of sodium sulfite at 165 degrees F by single coupon method.

Test Results

In order to establish that the volume of gas collected over potassium hydroxide solution was a true measure of the corrosion rate, a coupon was allowed to corrode in the apparatus for seven hours and the gas was collected over potassium hydroxide solution in a large buret. During that time 87.4 cc of gas were collected, calculated to standard conditions. The coupon was found to have lost 0.206 grams. This weight of SAE 1015 steel (99 percent iron) should liberate 90.5 cc of hydrogen at STP. An analysis showed no carbon dioxide or carbon monoxide to be present in the collected gas. Assuming, therefore, that the gas was pure hydrogen, the volume collected corresponds to 96.5 percent of the iron dissolved from the coupon.

The curve of a typical evaluation run is shown in Figure 4. Data for this and subsequent runs reported were taken by means of the gas buret for determination of hydrogen evolution rate. The figure shows the effect of 100 ppm sodium sulfite on hydrogen evolution rate for a steel coupon in a solution con-

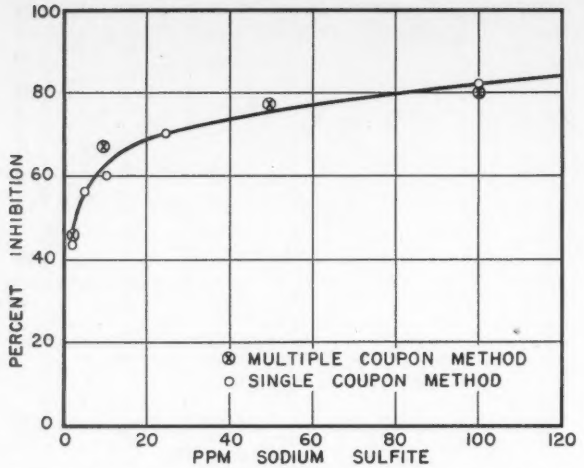

Figure 7—Inhibitor effectiveness vs concentration for sodium sulfite at 165 degrees F. Both single and multiple coupon methods.

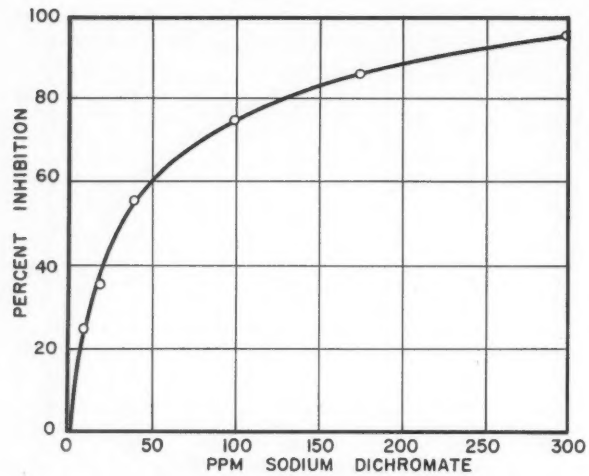

Figure 8—Inhibitor effectiveness vs concentration of sodium dichromate dihydrate at 155 degrees F. Single coupon method.

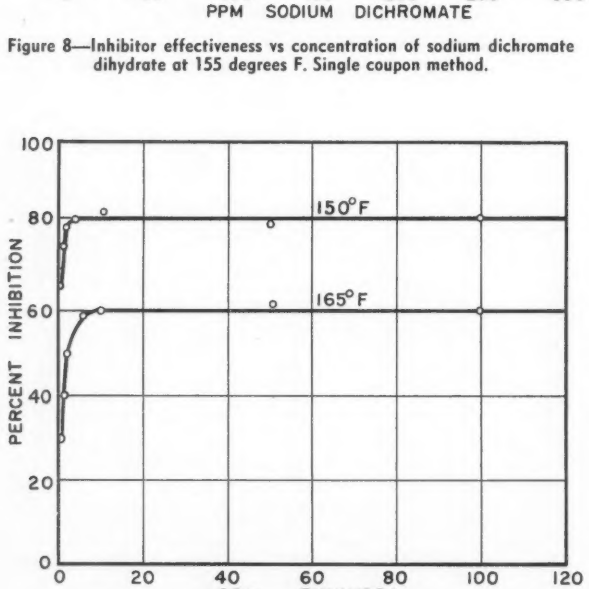

Figure 9—Effect of temperature on inhibitor effectiveness of thiourea. Single coupon method.

taining three percent sodium chloride and which was saturated with carbon dioxide. The curve shows the rate of decrease of corrosion during initial treatment, the maximum inhibitor effectiveness achieved and the persistency of the film after treatment was stopped.

Effect of several different concentrations of sodium sulfite is shown in Figure 5. Smooth curves are drawn for evaluation of 2, 10, 50 and 100 ppm inhibitor. Each concentration was tested on a different coupon. Evaluation of an inhibitor by use of a number of coupons is referred to hereafter as the multiple coupon method.

Another type of evaluation procedure using sodium sulfite is shown in Figure 6, in which a single coupon was subjected successively to increasing concentration of inhibitor. This procedure is referred to as the single coupon method.

Figure 7 shows the data of Figures 5 and 6 plotted as inhibitor effectiveness versus concentration. Values shown for percent effectiveness were calculated from the relative heights of flat portions of the curves in Figures 5 and 6. Points derived from both single and multiple coupon methods are shown on the curve.

The plot of inhibitor effectiveness versus concentration for sodium dichromate is shown in Figure 8. The same type of curve for thiourea at two different temperatures is shown in Figure 9. Data for Figures 8 and 9 were obtained by the single coupon method.

Table I presents evaluation results obtained by the hydrogen evolution method for a number of compounds of different types.

Discussion

Valuable criteria for inhibitor evaluation which can be obtained directly from results of the hydrogen evolution method are as follows:

1) Rate of decrease of corrosion immediately after inhibitor injection.
2) Inhibitor effectiveness as a function of concentration.
3) Persistency of inhibitor film after injection is stopped.

In Figure 4, the slope of that part of the curve between points A and B indicates the rate of decrease of corrosion immediately after inhibitor in-

TABLE I

Inhibitor Effectiveness as Determined by Hydrogen Evolution Method for Several Substances with Different Functional Groups

SUBSTANCE	Concentration ppm	Temperature °F.	Per Cent Inhibition
Butyl mercaptan	50	150	43
Diethyl aniline	100	165	0
Dibutyl disulfide	40	150	30
Diethyl sulfide	25	150	0
Dithiocarbonic acid	50	150	63
Naphthenic acids	100	165	7
Petroleum sulfonates	100	165	5
Pyrrole	100	165	0
Quinoline	100	165	0
Sodium dichromate	50	165	60
Soldium sulfite	50	165	75
Thiophene	100	165	0
Thiourea	50	165	60
Tributylamine	100	165	0

jection. Effective inhibitors usually give a more rapid decrease in corrosion rate than do poor ones. A steep initial slope, however, is not always accompanied by high inhibitor effectiveness. For example, Figure 4 shows that sodium sulfite reacts rapidly and yet is not highly effective. The percentage decrease in corrosion rate from point A to point C measures the effectiveness of the inhibitor. Thus, the effectiveness of sodium sulfite at 100 ppm is seen to be 80 percent.

The slope of that part of the curve between points D and E is used to measure the persistency of the protective film produced by the inhibitor. For purposes of comparing the persistency of films from different inhibitors, a quantity called persistency index is used. Persistency index is defined as the reciprocal of the average slope of the line between point D where injection was stopped and point E where the film provides a protection which is only one-half the protection at D. The persistency index of sodium sulfite calculated from Figure 4 is about 2. Indices ranging from 0.1 to 20 have been observed for different inhibitors.

Figure 5 shows the effect of concentration on the initial rate of inhibition and on the final effectiveness. As shown by the curves for sodium sulfite, corrosion rate is found generally to decrease more rapidly with increase of inhibitor concentration. The single coupon method, illustrated in Figure 6, provides a more rapid method of obtaining evaluation data for several concentrations of inhibitor when only final inhibitor effectiveness is desired.

The relationship between inhibitor effectiveness and concentration is obtained more readily from the type of curve shown in Figure 7. The maximum effectiveness to be expected from a specific concentration can be read directly from the curve. Figure 7 also shows that results from the single coupon method agree with those from the multiple coupon method.

Figure 9 shows that effectiveness of an inhibitor may reach a maximum at a specific concentration. This means that partial protection by an inhibitor at low concentration cannot always be increased by use of more inhibitor. Note that the effectiveness of the reactant type inhibitor, sodium dichromate, increases continuously with increase of concentration; whereas effectiveness of the adsorbed type inhibitor, thiourea, reaches a limiting effectiveness at low concentration.

Selection of substances suitable as oil well corrosion inhibitors by use of the hydrogen evolution method gives results which are often surprising in view of the results of inhibitor studies to be found in the literature. Many of the previous studies were carried out in corrosive solutions far different from those found in oil wells. Accordingly, conclusions drawn from such results should not be applied to oil well treatment without further testing.

Table II gives examples which illustrate how test results from strong acid solutions and high inhibitor concentration can be misleading when applied to weak acid solutions and low inhibitor concentrations. As can be seen, all of the compounds would be classified as good inhibitors on the basis of literature values, but would not be effective as oil well inhibitors for carbonic acid corrosion. The inhibitor concentration shown in the table for the hydrogen evolution method is the highest concentration considered economical for oil well treatment. Values in the last column of the table are taken from Table I in the preceding section.

TABLE II
Comparison of Inhibitor Effectiveness Under Different Conditions

SUBSTANCE	LITERATURE		Hydrogen Evolution Method*
	Conditions	Percent Inhibition	Per Cent Inhibition
Tri-n-butylamine[1]	0.7% in IN H_2SO_4 at 77° F.	97	0
N, N-Diethylaniline[2]	0.1% in IN H_2SO_4 at 77° F.	90	0
Pyrrole[3]	2% in IN H_2SO_4 at 140° F.	94	0
Quinoline[3]	2% in IN H_2SO_4 at 140° F.	85	0

* Inhibitor concentration 0.01 percent, temperature 165° F.
1, 2, 3. References at end of paper.

TABLE III
Results of Different Evaluation Tests in Carbonic Acid Solution

SUBSTANCE	LITERATURE		Hydrogen Evolution Method*
	Conditions	Percent Inhibition	Per Cent Inhibition
Naphthenic acids[4]	0.01% at 150° F.	95	7
Petroleum sulfonates[4]	0.01% at 150° F.	95	5
Diethyl sulfides[5]	1% at 170° F.	96	3
Thiophene[5]	1% at 170° F.	79	0

* Inhibitor concentration 0.01 percent, temperature 165° F.
4, 5. References at end of paper.

Results from many other studies are also of limited application because tests were carried out in closed or static systems, wherein concentration of corrosion products could build up in presence of the test coupon. Even for such studies made in carbonic acid solutions, results should not be applied to oil well treatment without further testing. Table III gives examples which illustrate how results from closed systems of carbonic acid can be misleading when applied to systems where carbonic acid is continuously renewed.

Results from the above tests of napthenic acid and petroleum sulfonates, all made at California Research on similar samples, show the extreme effect that renewal of the solution may have on inhibitor effectiveness. Differences shown for the last two inhibitors, diethyl sulfide and thiophene, cannot be attributed entirely to solution renewal in the evolution method, inasmuch as concentrations tested were also different.

It is evident that evaluation data obtained under one set of conditions may not apply even qualitatively under a different set of conditions.

Results presented in this paper have been confined to corrosion studies using carbonic acid-sodium chloride solutions. The method is readily adaptable, however, to study of corrosive effects of hydrogen sulfide, organic acids and water soluble salts. If combinations of volatile

acids are used, the thermal conductivity unit cannot be used without troublesome calibration.

Although corrosion in oil-brine systems can be studied more satisfactorily in a different apparatus, a special procedure was devised to determine whether the effectiveness of an inhibitor would be changed if it were injected in the presence of oil. A test coupon was agitated in an air-free mixture of oil and water containing the desired inhibitor. After one-half hour, the coupon was removed from the mixture and its corrosion rate followed in the hydrogen evolution apparatus. Results from this test would be equivalent to those given by the last portion of the curve in Figure 4 from points D to E. In general, the inhibited rates for a series of compounds tested by this method showed qualitative agreement with rates found by the usual method.

The hydrogen evolution method does not give complete evaluation of chemicals as oil well inhibitors, but it does provide a rapid and convenient means for screening a large number of potential inhibitors.

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1. C. A. Mann, B. E. Lauer, and C. T. Hultin. *Ind. Eng. Chem.*, **28**, 159 (1936).
2. Mann, et al., *ibid*, **28**, 1048 (1936).
3. F. H. Rhodes, and W. E. Khun, *Ind. Eng. Chem.*, **21**, 1066 (1929).
4. Unpublished California Research Corporation results.
5. P. S. Viles, and E. Q. Camp. U. S. Patent 2,474,603 (to Standard Oil Development Company) June 28, 1949.

ERRATA

Gasoline Resistant Tank Coatings. *Corrosion*, **8**, No. 6, 195-204 (1952) June.

Page 195. Delete from the abstract the fourth paragraph beginning: "A discussion of the problems of coating . . . ."

Page 197, substitute the paragraphs below for those in column one beginning with the words: "Figure 6 . . ."

The polysulfide-type material was applied at an average thickness of 13.1 mils (52 measurements taken; minimum reading, 8 mils; maximum reading, 19 mils). This involved an initial brush coat, followed by three spray coats. The vinyl-type material was applied at an average thickness of 7.4 mils (53 measurements taken; minimum reading, 5 mils; maximum reading, 12 mils). This involved an initial brush coat, followed by five spray coats. The Saran-type material was applied at an average thickness of 7.1 mils (35 measurements taken; minimum reading, 5 mils; maximum reading, 10 mils). This required five brush coats.

Figure 6 shows an area of the tank after coating with the Polysulfide-type material. Figure 7 shows the same area after being in service for 19 months.

Transposing the two paragraphs involved.

Page 201, table at bottom of page, under headings, "Barrels, 50,000" in rightmost column, second item from bottom, change to read:

Two-25,000

Changing the figure 2 to the word "Two."

Page 202, left column, fourth paragraph beginning: "a. Using a Type . . .," substitute the following two lines for the second and third lines of the paragraph:

---

ing a spray gun with a number 64 air cap and AV-15-D fluid tip. Pressure tank should be oper-

---

Changing the number 62 to 64 and the designation AV-15-AC-N to AV-15-D.

Vigilance Underground*

A Summary of Progress on Preventing Electrochemical Corrosion on Buried Pipe Lines

By BRYAN PATTERSON

BRYAN PATTERSON—Western manager for Hill, Hubbell & Co., has been specializing in protecting metals against corrosion since 1937 when he was experimental engineer for Plastics Division of Firestone Tire & Rubber Co., Akron. Since 1939 with Hill, Hubbell he has had extensive pipe protection experience. A registered engineer, he was trained at Utah University and Carnegie Institute. He supervised volume processing of DDT during World War II with army engineers. He is an NACE member.

Abstract

The need for control of corrosion on underground metal is explained and elements of planning electrochemical control outlined. Principles of weighing dielectric control with economics are given and limitations and sequence of recommended dielectric tests are listed.

A survey of common specifications and inspection fundamentals is followed by recommendations concerning electronic inspection after lines are in service.

Introduction

BACK in the gold-rush "days of Forty-Nine" the pioneer "vigilantes" considered it their civic duty to fight undermining forces or subversive actions threatening public welfare.

Today, in the present "Steel Age," corrosion engineers have a definite job of vigilance as guardians against rust, electrolysis, galvanic action and other agents of corrosion. Today public welfare leans very heavily on steel and other metallic structures for support in all phases of daily life. It is impossible to think of present day living without including steel and other metals in industrial framework, arteries of supply and fabric of communication.

The subversive activities of the agents of corrosion are varied and complex. The breadth of the field of corrosion mitigation requires concentration on specific problems. This article will attempt to summarize current practices of providing insulation and protection against electrochemical corrosion of buried pipe lines.

1. Corrosion Demands Vigilant Control

Before a recent United Nations conference on the conservation of the world's resources, Dr. H. H. Uhlig of the Massachusetts Institute of Technology gave an estimate of 5½ billion dollars annually for the cost of corrosion.

Underground corrosion in the U. S. A. accounts for over a billion dollars alone. In this country there are 1,600,000 miles of buried metal, including pipe, cable, conduit, and rail track. Pipe lines underground measure over 500,000 miles with an estimated value of 10 billion dollars. Annual corrosion loss in the oil industry alone is between 200 and 300 million dollars. Several major oil companies budget over a million dollars each year for corrosion reconditioning work, mainly on pipe lines.[1]

> "Corrosion is an electrochemical action. It illustrates tendency of all things to return to their source in nature. Just as the trees in the forest revert, eventually to the soil from which they sprang, so steel pipe buried in the earth will also revert to the iron oxide from which it was originally produced, *unless the cyclical conditions of nature are arrested!*"[2]

Old Mother Nature, who gives the many benefits of steel and other metals refined from her earth-held ores, also imposes on us the job of *continual vigilance* to see that her refined metals do not rust back to their original earthen state. On buried pipe lines corrosion is allowed a running start back to its place of origin *unless vigilant control is exercised* to retard electrochemical action—which starts as soon as the pipe goes underground.

Progress of NACE on Electrochemical Corrosion

The National Association of Corrosion Engineers is accomplishing much toward the prevention and correction of corrosion in all forms. Dr. H. H. Uhlig in his United Nations report said corrosion cost could be reduced 20 percent by a comprehensive corrosion control program. That would be a saving of over a billion dollars a year. The NACE is helping all the heavy industries such as oil, steel, chemicals, natural gas, power, telephone companies and many others. The mutual cooperation among engineers in industry and among industries is responsible for much recent progress especially toward improved standards. Each year there is a better understanding of the mutual problems of retarding electrochemical corrosion.

Necessity for a Corrosion Control Program

One of the main problems corrosion engineers have right now is to put the results of research and modernized techniques into practical operation. Corrosion engineers have assembled plenty of evidence to refute the old practice of *"put it in the ground and see what happens."* Most companies readily recognize it as sound policy to *prevent corrosion from the start,* but many

★Presented at a Western Regional Meeting, National Association of Corrosion Engineers, Los Angeles, Cal., November 9, 1951.

companies have not yet put a complete advance protection program into effect, even though it has been well proved that a planned control program *will pay out.*

Quoting a recent statement by the general manager of one of the leading oil and gas companies:

> "Some top executives are slow to recognize the direct losses from corrosion, and to connect its many indirect losses with their cause. Some of them are super-salesmen or business administrators, quite unfamiliar with the electrochemical mechanisms of corrosion. And some operators and engineers have insufficient data on the past costs of corrosion, and on the effectiveness and pay-out of preventative measures, to sell their need up to the top."[1]

But most progressive operators over the country recognize the necessity for a well-designed, economically-balanced program.

2. Planning Electrochemical Control

The first step in planning an electrochemical program for effective corrosion control is to combine cathodic protection with insulation of substantial dielectric strength.

Provision should be made in initial design for proper balance of cathodic protection and dielectric insulation. The following is quoted from a paper at this year's AGA Operating Section Meeting written by Clyde McGraw of the Transcontinental Gas Pipe Line Corporation, entitled—

> "WHY WE INCORPORATE A CORROSION CONTROL PROGRAM IN THE EARLY STAGES OF CONSTRUCTION OF A MODERN GAS SYSTEM."
>
> "Protective coating and cathodic protection go hand in hand. If the coating is not quite perfect then the cathodic protection makes up the difference. Because of the effective, though not perfect, insulation, one cathodic unit may protect 50 miles of coated pipe instead of 500 feet of bare pipe, thus the cost of operation is nominal. The economic and most ideal corrosion control program is one in which protective coating and cathodic protection are used in conjunction with each other."
>
> "No known methods of soil survey technique can predict with satisfactory accuracy exactly where, or how severe pipe line corrosion may be."
>
> "The history of other pipe line companies reveals that the soil in practically all states where there are underground structures is corrosive to some extent. This indicates the desirability and even the necessity of continuous pipe line coating."[3]

Transcontinental recognized that the ideal time to install protection was in the *original design and construction.*

> "The first step taken by the Transcontinental Gas Pipe Line Corp., was a general one of providing insulation by coating the pipe with a coal tar base enamel and fibre glass reinforcing wrapping *for the entire line.*"[3]

In "hot-spots," extra coating was used by Transcontinental and the whole program incorporated advance precautions looking toward eventual cathodic protection.

Protecting Safety Factors on High Pressure Lines

Today, high-carbon steel pipe lines are carrying heavy pressures with walls often 25 percent lighter than used 20 years ago. The necessity of using advance corrosion precaution on high-pressure light-wall lines is obvious. Safety factors in high-pressure lines are improved by the stronger steel. But the rates of corrosion and pitting are not reduced except by planned mitigation. Extra precautions of corrosion control on high pressure lines is not a new procedure. As long ago as 1910, Allen Hazen, developer of the Hazen-Williams formula for the coefficient of friction, "C" factor, said, regarding pipe design—

> "It is my feeling that it will not generally pay to increase the thickness of the plates, but the money will be better spent in better coatings and in more careful inspection."[4]

Mr. McGraw in his recent corrosion report to the AGA explained why his own company used extra precautions on their high pressure lines,

> "It is far more essential to adequately protect a thin wall pipe than a heavier pipe against corrosion, since pitting, which would not be harmful in the heavier pipe, may lead to failure on the thin pipe."[5]

Improvements in Modern Dielectric Insulation

The dielectric strength of pipe coatings is continually being improved, and each year brings more progress. In 1938 it was reported:

> "The newer wrappings are inherently more waterproof, therefore more electricity resistant and it is now possible to fully protect perhaps five or more miles of 8-inch wrapped pipe with fractions of an ampere and one cathodic station."[6]

For efficient operation of cathodic protection the Underwriters Laboratory recommends adequate dielectric insulation:

> "The pipe should be thoroughly coated with an impervious material of *high electric resistance* that can be applied with *few discontinuities.*"[7]

Each year new records are made in the length and size of coated lines which have been protected economically with a minimum of anodes or rectifiers.

One of the leading anode makers has just issued a bulletin on the comparative dielectric results of various lines:

> "While the complete protection of a bare line may require from 0.75 to 5.0 ma of current per square foot of surface area, a new well-coated line will require only from 0.01 to 0.02 ma per square foot."[8]

To maintain a pipe-to-soil potential of 1.00 volt, the usual practice is to estimate a current density requirement of .01 to .01½ ma per square foot on a well-coated line. Protection of a bare line will require from 50 to 500 times more current than a coated line. Cathodic stations will protect 20 to 25 miles of coated lines compared to one mile of bare pipe.

3. Dielectric Control With Economic Balance

The necessity of a corrosion control program that is well-designed and economically balanced has been mentioned—a plan which is technically sound and commercially practicable—*a program that will "pay out."* To quote again:

> "It is one thing to plan and design a theoretically ideal protective coating and quite another to achieve it in an economical and practical manner. The question of steel pipe protection is essentially an economic one and this factor should not and cannot be overlooked."[9]

To secure economic balance in an electrochemical program, insulation should be chosen for its permanent dielectric value and combined in proper economic combination with cathodic protection.

It is impractical to try for a theoretically "perfect" insulating material.

> "A pipe line could be protected by a perfect coating, one which contained no voids and which would remain impervious for a long period of time. From a practical point of view, there are many reasons why we cannot attain this type of coating."

It is likewise impractical to install a line with no coating, for economical permanent protection

> "If we choose to lay a line without coating we could apply cathodic protection, but the number of cathodic units required and the total power necessary to operate them becomes prohibitive."[10]

Tests and Standards for Dielectric Materials

Before World War II several series of tests were made to compare the strength and endurance of various underground pipe coatings. Some were accelerated tests carried out in laboratories and some were tests on short lengths of pipe buried in the ground. No comprehensive program was instituted for comparing and testing *actual operating lines on a national scale.* However, the pre-war tests did serve to weed out many coatings that were too costly or too weak in dielectric strength. Some of the facts brought out by the AGA and API tests were:

1. Physical and chemical properties must be stable and inert.
2. Hot-applied coatings showed better dielectric value than cold materials.
3. Shielding or reinforcement yields a definite economic advantage.
4. Methods of application are as important as materials selected.[11]

Probably one of the greatest contributions of the tests was to make pipe line men corrosion-conscious (if their own leakage and replacement problems had not already done so). In his report on the tests, Dr. Scott Ewing, supervisor, stated:

> "At the time these tests started, the practice was to brush, smear, or daub the coating material on the pipe.
> "When the pipe *looked black* it was considered coated!"[12]

Today, more definite standards are available and very effective tests are now employed.

Electronic Testing Using High Voltage

The electronic holiday detector is one of the most useful instruments for testing the continuity of advance insulation. By applying from 5,000 to 30,000 volts, usually in rapid individual impulses from 20 to 40 per second, voids, skips, holidays, or pinholes can be detected.

The AWWA recommends adjustment to 8,000 to 12,000 volts for testing coal tar enamel 2/32-inch to 3/32-inch thick, but otherwise there have been few definite standards established for inspection with high voltage.[13]

Thus far, the API and AGA have not set up definite voltage requirements. At the NACE conference in New York in March questions were submitted the Open Forum which indicated much interest in this problem:

> "How 'hot' (voltage) should a 'jeep' be for testing pipe line coatings?
> "Do the manufacturers of coal tar enamels have a recommended minimum and maximum valtage for detecting coatings in the field of 3/32-inch to 5/32-inch thickness?"[14]

Committees have been appointed by the AWWA to make further studies and set up recommendations for standards on high voltage tests.

Instead of voltage, the Dutch Corrosion Committee has adopted the length of spark as their inspection standard. Because of differences in design and operation of various detectors, a check should always be made on the length of spark produced. Usually a spark should be about twice the thickness, but not more than three times the thickness of the coating.

The purpose of electronic tests is to secure a continuous coating of sufficient insulation value to support cathodic protection at reasonable cost.

Because cathodic protection is effective with only one or two volts of p/s potential, it obviously is not the primary purpose of electric inspection to show that the material will stand thousands of volts. The reason for using high voltage is to provide a long enough spark to bridge the thickness of the coating and reveal any bare metal, voids, gaps, or misses in the coating.

> By electric testing the coating with a spark about twice the thickness of the coating a continuous coating will be assured, with any areas of bare pipe or exposed metal held to a minimum. *Electric testing must be followed up by careful installation* of the pipe including close supervision of the backfilling. It is obvious that *one* skid-mark or unrepaired scar will have more square inches of bare metal than hundreds of pinholes combined.

Limitations of Electronic Tests

High voltage inspection should be supervised carefully and controlled according to the thickness of the coating. Too much voltage will destroy good coating of adequate dielectric strength for successful cathodic protection.

> To obtain an equivalent test of continuity, a spark one inch long can safely be used on a coating a half-inth thick, while a 1/16-inch coating can be tested safely with not more than a 3/16-inch spark. Higher voltage will not materially reduce the total amount of square feet of metal by finding more voids or air gaps. On the other hand, excessive voltage will puncture numerous pinholes through the sealed insulation, requiring unnecessary repairs.[14]

Factors to keep in mind in making electronic tests are dryness of coating, humidity of the air, altitude, corona effects, clarity of signals, intervals of voltage impulses, as well as the thickness and type of coating being tested.

It must always be remembered that "absence of voids" is not a complete test and that several

additional inspection checks should be used to assure permanent service underground.

Dielectric Inspection Checks

The following checks on the insulation should be made, in addition to electronic inspection.

1. **Is the material inert?**
   Some materials pass a detector very well, but lose their insulation value after aging in the ground. The insulation material should be permanently inactive to both soil and metal. The wrapping or shielding materials also should be inert and inactive.
2. **Is the coating impermeable?**
   Some materials test well when dry, but lose some of their insulation or dielectric value when damp or wet in underground conditions.
3. **Is the coating tightly bonded?**
   100% tight, solid bond is essential to permanent life underground. The detector does not prove this by itself, and a close check on pipe cleaning, primer-curing, and application is needed.
4. **Homogeneous materials?**
   Some materials contain thinners or mixtures of dissimilar materials which in time lose their original dielectric value.
5. **Hot or cold application?**
   Most cold applications depend on evaporation for hardening. Thermoplastic (hot-applied) coatings do not alter their insulation value if properly applied at the approved molten state.
6. **Multiple coat or single coat?**
   According to exhaustive tests, "Multiple application automatically minimize the probability of continuous imperfections through the protective material."[15]
7. **Mechanical strength as well as dielectric strength?**
   The coating must be capable of resisting underground soil stress and physical forces of varying degrees. While padding or external shielding can be provided, the coating materials themselves should have reasonable mechanical strength.

The final test of practical dielectric value is in the length of useful service underground. There are many variables in underground conditions, including changes in soil acidity, moisture content, aeration, soil stress, stray currents, temperature changes, etc., which will make more severe ultimate tests than can be given in accelerated tests above-ground. But the above checks, plus electric inspection, will greatly reduce chances of failure underground.

Standardization of Insulating Materials

In addition to the customary inspection checks, the engineer should of course be guided by previous service records, experience of manufacturers and special conditions of the job.

Not long ago there were dozens of types of materials used for coating underground lines. Only 20 years ago, one of the leading applicators needed over 100 combinations of coating and wrapping specifications to handle various jobs over the country. The API and AGA tests, plus practical experience of pipe line owners, have reduced the list to four or five outstanding standard materials today, including coal tar enamels, asphalt coatings, wax-type coatings and cement combinations. Many kinds of wrapping have also been used over the years, including cloth, burlap, metal foil, plastic films, wood, etc. Apparently, for underground use, asbestos felt and fiber glass have best survived the tests of time and experience.

Improvements continually are being made in the standardization of insulation materials. For example, coal tar enamel is now manufactured in three grades, as follows:

1. Regular Enamel—refined coal tar pitch—also called pipe line enamel and standard enamel.
2. Semi-plasticized Enamel—also called intermediate, modified, 60-40 blend, or medium enamel.
3. Plasticized Enamel—coal tar derivative pitch—also known as waterworks enamel and winter enamel.

Factors to consider in choice of materials are—condition of pipe, terrain of pipe line, season of year, permanence of line, accessibility for repairs, availability of skilled labor, weather conditions, etc.

Each of the widely used types of materials has certain built-in advantages that can be utilized in specific construction conditions.

4. Specifications and Inspection Fundamentals

Pipe line coating progress has been stimulated along with other phases of pipe line design and construction during the recent rapid-expansion period.

> "Perhaps the most significant development in the pipe coating field during the past few years has been the improvement in the *methods of applying* the protective coatings."[16]

A total of several million dollars is now invested in coating plants equipped to provide more favorable conditions and techniques for economical insulation.

> "Application by professionals is economical and provides specialized and experienced coating service not usually available within the owner's organization."[17]

Most pipe line builders agree with the findings of the API, AGA and Bureau of Standards tests, that results are proportionate to the care and methods of application. But care of workmanship has been sometimes overlooked.

> "The coating of the pipe usually has been the most bothersome operation in the construction of a pipeline. It is no reflection on the pipeline builder to say he has not always coated the pipe properly. He must have had great ability and resourcefulness and exceptionally good men to have done as well as he has."[18]

Engineers today are more corrosion-conscious and now that improved equipment and facilities are available, better jobs are being specified and installed.

Standards of Workmanship in Application

Available standards are the American Waterworks Association Specification 7A-6—1950 and the API "Tentative Code of Good Practice." Committees are

at work to improve these standards from year to year. The AWWA specification is the most complete at present, with the following items mentioned:

Pipe Preparation—Cleaned to a bright metal, preferably by blasting. Primed with exact quantities uniformly dispersed and carefully dried for proper cure with controlled temperature.

Coating Application—Bonded absolutely tight to metal —uniform and continuous.

Wrapping Application—Tight and smooth, with no buckles or gaps.

Loading and Shipping—To approved American Association standards, which specify unit-loading and provide for warranted safe delivery.[13]

The quality of workmanship depends on experienced, permanent crews, and on *trained, vigilant supervision.*

> "The engineer must be guided by the knowledge and experience of the operators, their past service records, and ability to comply with spcifications in every detail."[19]

Many variables must be controlled, including the condition of pipe, temperatures, dust conditions, size of job, etc.

> "It requires especially capable foremen to have properly heated bitumen in sufficient quantity and neither too hot or too cold. The pipe must be perfectly dry and clean before it is primed and must be primed far enough but not too far in advance of the coating. Considering all these things the contractor can hardly be expected to be concerned over a few small pinholes or bare places in the coating. Yet these flaws must be prevented if the coating is to serve its intended purpose."[20]

The most suitable conditions for proper insulation are found indoors at the permanent mills, where new pipe can be processed conveniently and economically.

Safe Practices in Shipping and Transportation

If approved methods are followed, mill-wrapped pipe can be shipped long distances and handled safely to the pipe line trench even in the roughest mountain country.

The American Railroad Association has approved standard specifications for loading pipe for safe shipment, including warranty of satisfactory delivery. Most factory-wrapped pipe today is shipped with variations of the original Hill-Hubbell unit-load method on which the railroad association specifications are based.

> "Over 26,000 cars have been loaded by this method (before 1937) without a single claim against a carrier, thus demonstrating that mill coated and wrapped pipe can be shipped without damage in transit."[21]

The unit-load method essentially requires padding and banding of the entire carload into one bundle so there is no chafing of the pipe against the floor or sides of the gondola, nor between adjacent lengths of pipe. At the present time it is estimated that approximately 10,000 carloads of factory treated pipe is shipped each year. One coating company alone handled over 4000 carloads in 1950.

Transportation of coated pipe from railhead or storage yards can be handled with complete safety using wide-surface equipment. Most line-pipe these days is relatively thin-wall pipe. The pipe line builders try to keep the pipe ends round and true for welding, and avoid dents or damage to the steel itself. The slam-bang methods of 20 years ago are no longer used, even on bare pipe. In general, qualified pipe line contractors have equipment designed to handle wrapped pipe just as safely as bare pipe, including wide slings and wide-surface skids. In normal weather, coated pipe can be bent safely without breaking the insulation. Engineers usually require careful bending, especially on light pipe, to avoid kinking the steel. Coatings can be specified with sufficient plasticity to stand as much physical expansion as the steel.[22]

Inspection in Coordination with Field Construction

Coating specifications and inspection procedures are influenced by seasonal construction requirements. For winter installations, or for mountain work with warm days and cold nights, the plasticized types of insulation should be used. Regular, or standard enamel is used most in the warmer installations such as in the South and Southwest.

Construction schedules nowadays often depend on availability of the component materials as well as on seasons of the year. Many of the coating plants have storage space to assemble complete pipe stocks and then ship to suit construction schedules.

Improvements in methods of coating joints have been developed which considerably simplify the use of factory wrapped pipe. There are now available special joint coatings, including adhesive insulation tapes, hot-applied tapes, self-sealing compounds, dispensable jackets or molds for pouring hot coatings, as well as the well-known spiral-wrap or cigarette-wrap methods using the same materials as on the pipe. The choice of joint materials depends on type of installation, number of joints, accessibility, and other factors. In every method thorough inspection should be exercised, and enough joints should be electrically tested to check the workmanship of application as well as the insulation value of materials used.

Electronic Inspection After Lines Are in Service

It is possible to locate flaws or discontinuities in pipe insulation after lines are in service by using a Pearson detector or a CRC Faultometer. Basically, these instruments indicate weak spots in the insulation by amplifying the intensity of signals from exposed metal on the underground pipe. Many difficulties are encountered in getting satisfactory tests on conductance of lines in service, as the lines tested must be isolated from other lines or structures to obtain accurate readings.

In the AGA and API tests by Shepard and Ewing, it was found that certain precautions were necessary.

> "The chief sources of error are: 1) Polarization, 2) Galvanic potentials within the circuit, and 3) The movement of the electrolyte within the capillary pores electrosmosis)."[23]

A committee of seven NACE engineers has been working on this problem and recently reported that conductance can be measured "on top of" existing protection current, provided that all sacrificial anodes are

disconnected and all possible connections to other lines cut off so that the current is drained to one point.[24]

In general, the most effective procedure is to originally install lines with as nearly continuous advance insulation as possible and then fortify the electrochemical defense with cathodic protection. *No longer do experienced engineers follow the philosophy of "put it in and see what happens."*

Conclusions

The conservation of all metal is becoming a national necessity.

The NACE is growing rapidly, and with its 2500* members will in the future render more and more service in corrosion control.

Sectional and national conferences particularly show the interest and desire for progressive information on pipe line corrosion.

In the special field of pipe corrosion underground, much progress has been made, and is being made, on electrochemical protection.

The proper balance of carefully applied insulation and cathodic protection is a sound investment.

By pooling ideas and discussing mutual experiences, corrosion engineers can assist pipe line builders, manufacturers, and applicators, toward much further progress. *Concerted vigilance will get the job done.*

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* Over 3200 members in 1952.

DISCUSSION

Question: What is the Estimated Cost of Coating Joints?

Answer: The cost of coating joints varies according to accessibility and number available to coat at one time. With modern arc welding a 6-inch trim-back leaves a 12-inch gap to seal on each joint. This is 5 percent of the pipe surface on 20-foot pipe and 2½ percent on 40-foot pipe. Hand coating is usually estimated at twice the cost of mill coating per foot. The cost of coating joints, therefore, should be estimated at approximately 10 percent of the total coating cost.

Question: Should Hot or Cold Materials Be Used for Coating Joints?

Answer: This also depends on accessibility and amount of work for one operation. On pipe lines across open country, a 3 or 4-man crew coats one to two miles of pipe line joints per day with the hot cigarette-wrap method—using a wide piece of felt as a sling and also as a shield to seal each joint. But in a bell-hole job deep in a city trench, other methods are often more practical. Whether hot or cold materials, the success of a tightly sealed joint depends on the skill and the conscientious vigilance of the workmen.

Question: Does Kraft Paper Add to the Insulation Value?

Answer: No, except to help protect the coating underneath the paper. If applied tight and smooth without buckles, Kraft paper greatly reduces friction and abrasions. The paper also reflects solar heat and aids in storage and field handling.

Question: How High Should Coated Pipe Be Stacked in Storage?

Answer: A good guide is stack no higher than shipped, which is usually at from 200 to 300 pounds per square foot of supporting area in the railroad gondola.

Question: Can Large Pipe Be Shipped as Well as Small Pipe?

Answer: Yes, because large pipe with a wider radius distributes weight over a wider bearing surface. Thousands of cars of pre-coated pipe of 20 to 30-inch OD have been transported to all parts of the country, including remote mountain locations. Reasonable care and vigilance is all that is needed, same as on small pipe.

Question: Is it Practical to Use Cathodic Protection on City Lines?

Answer: Many complications do present themselves in congested industrial and residential districts, such as interference from other pipe lines, conduits, cables, etc. However, the hazards of leakage are also greater in congested city areas. If cathodic protection is not feasible, extra vigilance should be given to secure a holiday-free coating. Double wrapping is often specified as an extra precaution against expensive repairs in congested city districts.

Concrete for Sea Water Exposure With Particular Reference to Piling*

By HERBERT K. COOK*

Abstract

Samples of concrete exposed at Treat Island in Cobscook Bay, Maine by the Concrete Research Division of the Waterways Experiment Station, U. S. Army Corps of Engineers are subjected to as many as 14 reversals of freezing and thawing in one week. While influence of seawater sulfates on the concrete is believed to be insignificant at Treat Island the tests indicate conclusively that concrete containing an air-entraining agent is vastly more durable than those which do not contain it. Comparison of Treat Island samples with identical samples exposed at St. Augustine, Fla. indicates that in seawater below 40 degrees F attack on the cement by seawater itself is much less than in seawater of higher temperatures. Tests at St. Augustine indicate cements with more than 8 percent tri-calcium aluminate content will be attacked by seawater more readily than those of lower content. Air entrainment appears to have little effect on attack by sulfates. Seven-sack concrete is superior to five-sack concrete, 7-year seawater tests at Cape Cod show.

A method of encasing wooden piles damaged by marine organisms with concrete is described. The method involves placing a concentric sleeve about the piling, excavating by jets a volume below the mud line, filling the annular space thus created with selected aggregate and then injecting an intrusion mortar.

IT IS A GOOD basic assumption that the requirements for good concrete are just as applicable for marine piling as they are for other types of marine construction, or for any other type of concrete where durability is of paramount importance. The best possible protection for concrete for use in harbor construction is to have good concrete to start with. There is, indeed, no very satisfactory or economical way of protecting poor concrete. It therefore follows that any discussion of the protection of concrete should indicate the kind of concrete which will most satisfactorily resist the several types of exposure encountered in marine locations.

Concrete in such locations is exposed to all the various climatic conditions, depending upon geographical location, as any other concrete, plus the important fact that it is always exposed to severe moisture conditions and to the chemical effects of the seawater itself. Climatic exposure may, in general, be broken down into two major categories: 1) locations where freezing and thawing occurs, and 2) locations where no freezing and thawing occurs. There are, of course, under these two general conditions many variations in the degrees of exposure.

The effects of leaching action and of change in composition of the cement caused by the chlorides and sulfates in seawater are the effects which must be given special consideration. These essentially chemical actions are, of course, accelerated in locations where the temperature of the seawater is relatively high and are retarded where the water is colder. Where the air temperature is frequently below freezing in winter, the alternate effect of freezing by the air and thawing by the water becomes a serious problem, whereas in climates where no freezing occurs the presence of seawater as a solution becomes of more importance. Most marine structures are so located that both factors must be considered. Fortunately, recent developments in concrete technology make it possible to design concrete mixtures giving excellent service in locations of moderate climate and satisfactory service in locations of extremes. In any event, the quality of the aggregates, the control of the concrete proportions, and adherence to the best practice and workmanship in the placing and curing of the concrete are of vital importance in any marine location.

To return to the types of concrete best suited to conditions of extreme exposure, let us consider some data we have obtained as the concrete research organization of the Corps of Engineers and some additional data obtained by the Portland Cement Association. Two natural exposure stations are operated by the Waterways Experiment Station, of which the Concrete Research Division is a part. One is located at Treat Island, Maine, in Cobscook Bay, at the mouth of the Bay of Fundy. Since 1936 the resistance of concrete to severe natural weathering has been studied at this location. The major program for which the exposure station is now used was begun in the late summer of 1939 and has been continued since that time.

Figure 1 gives a general view of the installation of specimens on the exposure rack at Treat Island. Some conception can here be gained of the extreme range of tide at this location. The normal range is 18 feet, the maximum range 26 feet, and the minimum range 13 feet. The exposure rack is located at the mean, or half-tide, elevation. At normal high tide, the specimens on the rack are covered with nine feet of water.

Seawater moves into Cobscook Bay from the Bay of Fundy in great volume, with the result that the temperature of the water is remarkably uniform throughout the year varying from a low 34 degrees F in April to a high of 55 degrees F in early September. The temperature of the water six feet below the surface ranges from 35 to 38 degrees F during the months in which the air temperature is lowest, December through March. During these months, the air temperature averages about 14 degrees F, with

★ Reprinted from Proceedings, Wrightsville Beach Marine Conference, June 1950, where it appeared under the title "Concrete Piles and Their Protection in Harbor Construction."

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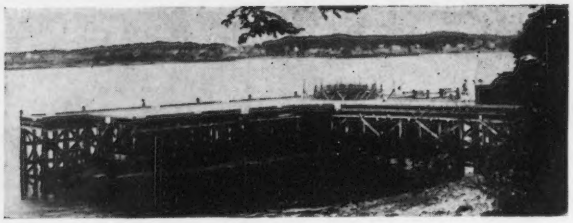

Figure 1—Rack at Treat Island.

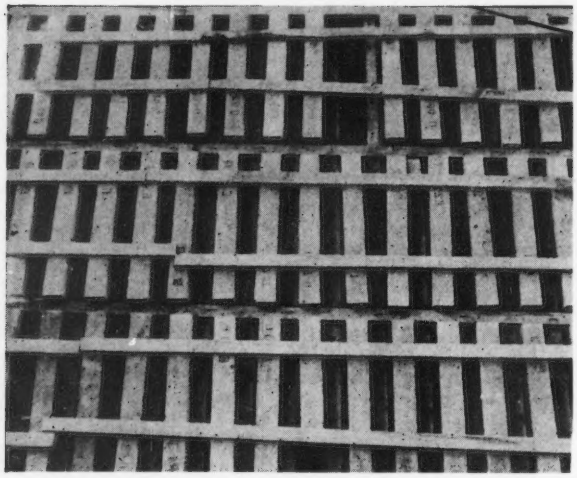

Figure 2—Columns at time of installations as viewed from top of wharf.

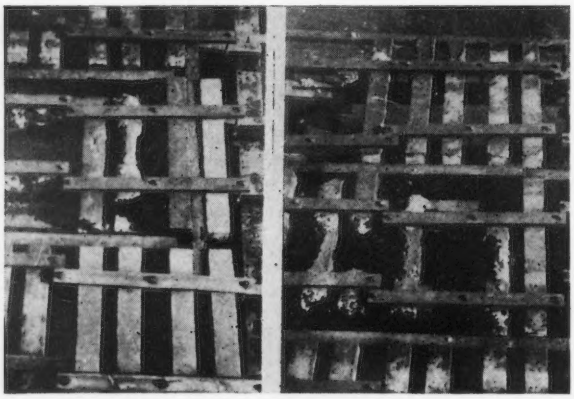

Figure 3—Appearance of specimens after one winter.

a normal low of —10 degrees F and a normal high of 36 degrees F.

The combination of air and water temperature creates a condition in which the specimens are thawed in water to a temperature of about 37 degrees F when covered at high tide and are frozen in air to a temperature of between —10 and +28 degrees F when exposed at low tide. The change from the frozen to the thawed condition and vice versa is extremely rapid, adding severe thermal shock to deterioration from frost action. Because of the combination of two reversals of tide per day, and the low temperatures which prevail during the winter months, it is not unusual to record 14 reversals of freezing and thawing in one week. The average number of cycles per season is 135.

Influence of the sulfates in the seawater at this location is believed to be insignificant. No evidence of such influence has been observed to date. The uniformly low temperature is not conducive to chemical action and the damaging effect of the severe weather is so great that few specimens without entrained air last long enough to permit chemical action to become a factor. Further evidence of the lack of chemical action as a factor in the deterioration of the specimens at Treat Island is the complete lack of any indication of deterioration of parallel specimens installed at the second exposure site of the Waterways Experiment Station at St. Augustine, Florida, where the warmer water is more conducive to chemical action.

The specimens located at Treat Island have developed a definitely significant range of durability varying from complete disintegration early in the first winter to no indication of distress after ten winters of exposure.

Figure 2 is a photograph taken from the top of the wharf looking down on the specimens. The basic specimen is a 6 in. x 6 in. by 4-ft. "column," so called because it was cast in a vertical position, the desire being to simulate vertical sections in structural concrete. The specimens shown contain 52 samples of Portland cement, collected from 47 mills distributed throughout the United States, and natural siliceous fine and coarse aggregate. For purposes of this phase of the investigation, all factors were maintained constant except the type of cement and the consistency of the mixtures. The cements were preponderantly of the type which, under present Federal Specification SS-C-192, would be Type II, although all types from I to V were included. The inclusion of treated Portland cement, or what now is known as an air-entraining cement, was incidental, since such cements were relatively unknown at the time and only five of this definite type were obtained. The fact that of the original 271 columns installed in 1940 only 19 containing treated cements are sound at this time is strong evidence of the remarkable increase in durability which air-entraining cements give to concrete.

Figure 3 shows how the specimens in the cement-exposure program looked after the first winter. It will be noticed that a number of the specimens have disappeared entirely, while others are in an advanced stage of disintegration and still others appear to be in perfect condition.

Figure 4 is a view of the exposure rack located at mean-tide elevation in Salt Run near St. Augustine, Florida. No freezing and thawing occurs at this location and the warm temperature of the water makes the installation valuable principally as a check against the results obtained at Treat Island. Any deterioration which occurs at the St. Augustine installation can be attributed only to chemical reaction between the seawater and the cement and to changes in temperature and moisture content of the concrete. The specimens installed here are identical and cast at the same time from the same batches as specimens installed at Treat Island. Although installed in 1940, only eight of the 156 specimens have failed. Six of

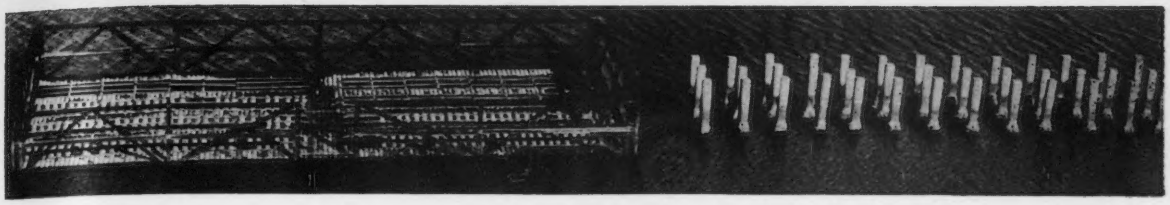

Figure 4—Rack at St. Augustine, Fla.

these were made with two cements with a high tricalcium aluminate content.

Specimens representing 18 different test programs have been or are now exposed at the principal exposure station at Treat Island, Maine. Data obtained there indicate conclusively that concrete containing an air-entraining agent will be vastly more durable when exposed to freezing and thawing in seawater than will concrete without such an agent. The test data also indicate that, in seawater below 40 degrees F, attack on the cement by the seawater itself is much less than in seawater of higher temperatures.

The test data from St. Augustine indicate that cements high in tricalcium aluminate (above 8 percent) will be attacked more readily by seawater than will cements with a tricalcium aluminate content less than 8 percent. Apparently air entrainment will effect no remarkable increase in the resistance of cement to attack by sulfate action, although information from other organizations indicates that it may increase such resistance to some extent.

The data obtained from these two exposure installations is too great to present at this time. It is, however, all contained in the First, Second, and Third Interim Reports, dated June 1942, July 1945, and August 1947 respectively, issued by the Waterways Experiment Station. Unfortunately, all three reports are now out of print. Loan copies only are available. It is contemplated that a Supplement to the Third Interim Report will be issued in July of this year, additional reports being planned for every two years thereafter.

The interesting data (Table 1) available from the Portland Cement Association, from their long-time study of cement performance in concrete, have to do with the experimental concrete piling subjected to severe seawater exposure for seven years at Cape Cod. It covers seven Type I and five Type II cements. Each type is represented by test piles containing five sacks of cement per cubic yard with a 2-inch slump, consolidated by vibration; seven sacks, 2-inch slump, consolidated by vibration, and seven sacks, 8-inch slump, hand-placed. The piles are visually inspected periodically and assigned a rating number based on their condition. A rating of 1 indicates no significant change since construction. Higher ratings indicate degrees of deterioration, a rating of approximately 9 representing complete disintegration so far as usefulness is concerned. The principal observation of interest is that the seven-sack concrete is superior to the five-sack so far as resistance to exposure is concerned. The same trend has been observed in concrete exposed to sulfate soils. One explanation is that, with the lower water-cement ratios that can be used with richer mixes, the porosity or permeability is lowered so that sulfate waters cannot so readily gain entrance. In general, the high-cement mixtures can be used quite readily in concrete piling. In massive concrete sections, however, the disadvantages of high heat development with consequent shrinkage, would undoubtedly outweigh the increased resistance to sulfate action.

It is interesting to compare the durability of concrete piles versus wood piles. The exposure rack at St. Augustine on which the Waterways Experiment Station concrete specimens are exposed was constructed in 1940 of creosote-impregnated timber piling and similarly treated timber decking. By February of 1950 the decking had been so attacked by marine borers that there was imminent danger of the concrete specimens falling through and several sections of the walkway were unsafe. All portions of the structure affected were close to the low-tide level. The piling itself was examined by a diver and found to be unaffected. Consequently, the decking on the original piling is being replaced with new creosote-impregnated timber.

In April of 1950 an inspection was made of our Treat Island exposure rack. This rack consists of a wharf, with 12 x 12-inch decking, constructed in 1936 in connection with the Passamoquoddy Tidal Power Project, plus an additional half-tide rack constructed in 1940. The piles for both portions of the

TABLE I

Rating of Piles in Sea Water After 7 Years of Severe Exposure[1]

Cement No.	5 Sacks, 2-Inch Slump, Vibrated	7 Sacks, 2-Inch Slump, Vibrated	7 Sacks, 8-Inch Slump, Hand-Placed
TYPE I CEMENTS			
11	2.2	1.1	1.2
12	1.9	1+	1+
13	4.2	1+	1.3
14	2.5	1.0	1.2
15	2.2	1.1	1.0
16	1.8	1.1	1.1
18	2.6	1.1	1+
Average	2.5	1.1	1.1
TYPE II CEMENTS			
21	6.0	1.1	1.3
22	1.8	1.1	1.2
23	2.0	1.2	1+
24	2.0	1.1	1.5
25	1.1	1.3	1.0
Average	2.6	1.2	1.2

[1] Rating of 1 indicates no significant change since construction.
Higher ratings indicate degrees of deterioration with a rating of approximately 9 representing complete disintegration so far as usefulness is concerned.

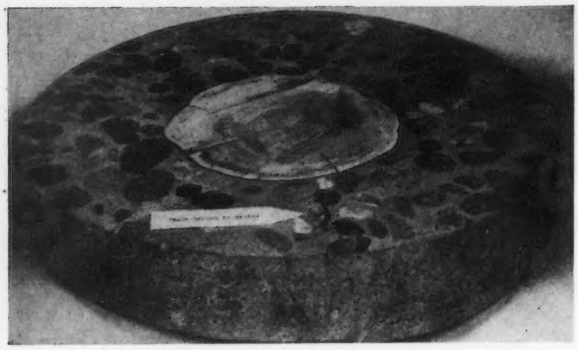

Figure 5—Slice from Prepakt encased pile.

structure are untreated. The wharf piling has been attacked by marine borers at the mud line. In a few cases the diameter of original 14- to 16-inch piling has been necked down to zero. In many instances the reduction in diameter amounts to several inches. A few of the wharf piles appear to be unaffected. The rack piling appears to be unaffected, but it has not been exposed as long.

Because of the prohibitive cost of removing the heavy 12 x 12-inch decking, plus an elaborate system of cross and sway bracing, which would be required to replace the large number of piles affected, the piles are being encased in Prepakt concrete from the bottom to slightly below half-tide level. This method of placing concrete is particularly adaptable to underwater work, and, because of the extreme tides in this location, it appears to be an excellent means of making the desired repairs. After a pile has been cleaned of incrustations and slime, which in this location can be performed at low tide without the use of a diver, sheet metal tubes having a diameter six inches greater than that of the pile are assembled in sections above water and lowered sleeve-fashion to the bottom. To sink the forms a few feet below mud line, a temporary conical depression is excavated around each pile by the use of jets. Temporary spacers are desirable to assure concentric location of the form around the pile. Mud may be removed from the interior of the form by jets and flushing. The original spacers are removed and reinforcement cages with spacers of a wire-spring type or precast concrete blocks, are assembled around the pile and slid into place inside the form. The reinforcement should be positioned to provide at least 1½ inches of concrete cover on the outside.

Upon completion of this work, the form is set and sealed by pumping intrusion mortar into the cone previously jetted around the pile, and the form is pushed into it. After setting of the forms, they are filled with coarse aggregate graded from ⅜ inch to ¾ or 1 inch. The forms and reinforcement are then vibrated lightly to assure maximum aggregate content and complete filling. The coarse aggregate is then solidified by the injection of intrusion mortar, always from the lowest point in the form and usually by the placing of a grout pipe in the form prior to filling with the coarse aggregate.

Once the form is in place, the filling with aggregate and injection of the grout can be accomplished under water since the intrusion mortar has essentially no tendency toward dilution. It is composed of a mixture of sand, Portland cement, Alfesil, Intrusion Aid and water. A typical intrusion mortar for pile-encasement work would contain two bags of Portland cement, 1 bag (1 cu. ft.) of Alfesil, 2½ lb. of Intrusion Aid, 3 to 5 cu. ft. of sand and water.

The Alfesil is a finely divided siliceous material which combines with the lime liberated during hydration of the cement to form insoluble compounds contributing to long-continued strength gain and impermeability of the hardened mortar. The Intrusion Aid inhibits the early stiffening of the mortar, thereby facilitating pumping; reduces the water requirement for a given consistency; prevents the agglomeration of the cement particles; tends, in conjunction with Alfesil, to hold the solids in suspension; and produces a grout which expands slightly before final setting thereby tending to reduce setting shrinkage. The sand, finer than normal concrete sand, should have no more than 10 percent retained on the No. 16 sieve. The coarse aggregate should be such that 100 percent is retained on a ⅜-inch sieve. The gap between the smallest coarse aggregate and the largest fine aggregate permits complete filling of the voids without plugging.

Figure 5 shows a slice from an experimental pile encased by the means just described. This use of Prepakt concrete at Treat Island should at least result in a severe test of its capabilities.

In summary, the points to be considered in the protection of concrete piles in harbor construction are about three in number. First, the best protection is good concrete to start with. Second, use of air entrainment, with high-quality aggregates, a low water-cement ratio, a cement factor in the vicinity of seven sacks per cubic yard, adherence to good consolidation practices and good curing will produce the best type of concrete for seawater exposure where freezing and thawing is a factor. And, finally, the same type of concrete as just described, with a cement containing less than 8 percent tricalcium aluminate (Type II), is most satisfactory for marine locations where freezing and thawing is not a factor and where seawater temperatures are high. Although use of air entrainment in such concrete is not necessarily mandatory, the advantages to be gained in lowered water-cement ratios, increased workability and possible increase in sulfate resistance make its use highly desirable.

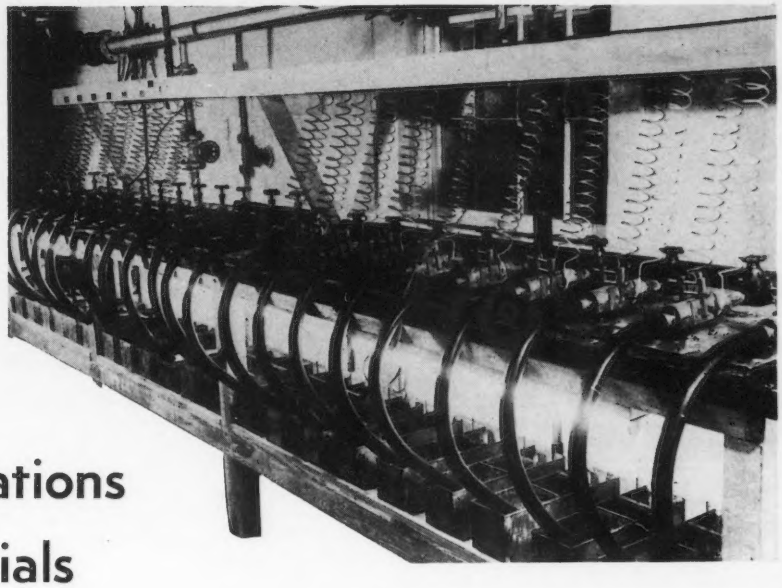

Figure 1—Test bench of 22 units showing potential measurement cells, valves, wier boxes and hook gages.

Some Observations Of the Potentials Of Stainless Steels in Flowing Sea Water *

By K. M. HUSTON and R. B. TEEL

WHEN TWO dissimilar metals are in contact or connected to each other in an electrolyte, one metal is often attacked at a much faster rate than usual, while the other metal either remains free from attack or is corroded at a considerably slower rate. Because corrosion of this type is always associated with the generation of an electric current, it is described as galvanic corrosion.

In their book "Corrosion Resistance of Metals and Alloys"[1] McKay and Worthington included an arrangement of metals and alloys in a practical galvanic series, based on the potentials of metals and alloys as measured in sea water.

Subsequently, LaQue and Cox[2] developed a similar series in which the data presented were the potentials of metals and alloys in sea water. Both of these treatments were more appropriate than references to the standard "Electromotive Force Series of Elements," which was sometimes used to predict the direction of galvanic effects. Charts showing the influence of varying relative electrode areas on the galvanic effects in combinations of many alloys were subsequently published in the "Corrosion Handbook."[3] ASTM Committee B-3 has also reported[4] the results of a five-year atmospheric exposure test of Types 304 and 316 stainless steels coupled with aluminum, lead, zinc, Monel, copper, bronze, and mild steel. All this information has been of considerable value in avoiding harmful galvanic effects in the commercial utilization of dissimilar metals.

The attractive corrosion resistance of stainless steels has resulted in their being used to an increas-

★ A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

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Abstract

Available information on the EMF potentials of stainless steels has been limited to a relatively few grades. There has been no information on neither the free-machining grades nor the new alloys. This article reports potentials in seawater of nine standard grades and three new grades of stainless steel. The effects of heat treatment, free-machining element and crevice corrosion on the EMF potentials are discussed. The relation of these potential values to those of other common alloys is indicated.

The testing equipment set-up at the Harbor Island Marine Test Station is described and illustrated by photographs.

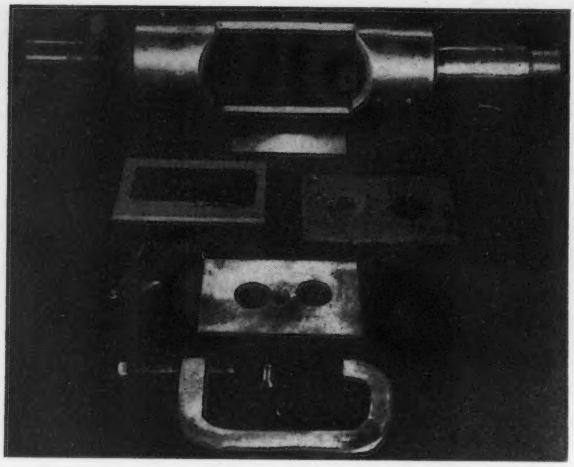


Figure 2—Apparatus for potential measurements in high velocity sea water (disassembled.)

ing extent to supplement and replace other metals in assemblies subjected to corrosion. In many instances, stainless steels may be connected to existing piping systems or to other assemblies where dissimilar materials are present. It is often necessary, therefore, to predict the galvanic effects that may result from such combinations. Because the galvanic relationships among metals are influenced by the nature of the environment and since data on a specific environment are generally not available, data referring to a particular environment, such as sea water are useful as a guide in making predictions. As an example, available sea water and atmospheric galvanic data were used in predicting the effect of stainless steel kettles, which replaced copper kettles, on an existing brass piping system.

Until recently, available information on the potentials of stainless steels in salt water was limited to Types 304 and 316. Inasmuch as the number of requests for information on galvanic effects was increasing and because there were no EMF potential data on the many other grades of stainless steel, arrangements were made to develop such data in the apparatus available for this purpose at the Harbor Island Experiment Station, where sea water was available as the corrosive medium.

This article describes the testing equipment and reports the EMF potentials measured on nine standard grades of stainless steel and three new alloys.

The apparatus now in use at Harbor Island differs from that described in the 1940 LaQue and Cox paper. It was designed so potential observations could be made at higher rates of water flow than were practical with the original test set-up. It consists of a battery of 22 units which receives sea water from a 3000 gallon rubber-lined constant level tank under a 42 foot head. The flow through each test unit is controlled on the inlet side with a diaphragm type valve. This valve, in conjunction with a weir box and hook gauge, provides for accurate control of water velocity in each test unit. In Figure 1 an overall view of the test bench with the 22 units, the valves, the weir boxes and the hook gauges is shown. The operation of the entire apparatus is very

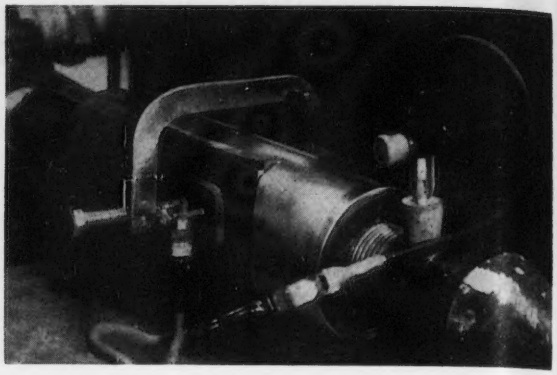


Figure 3—Apparatus for potential measurements in high velocity sea water.

flexible. As many as 44 different specimens may be tested in one run at various accurately controlled rates of flow.

The design and construction of the test units is rather complex. Figure 2 shows a test unit and its component parts. The body of each test unit is about 2½ inches in diameter by 7½ inches long and is machined from a solid hard-rubber rod encased in a Monel cylinder for reinforcement. As may be seen in Figure 2, the hard-rubber body is milled to provide a support for electrodes or test pieces which measure 2⅞ inches × 1 3/16 inch × ⅛ inch. When in place, these specimens form the walls of a channel through which water can pass. This channel measures ¼ inch wide by 1 inch high. The entrance and exit ends of the test chamber were machined to achieve a gradual change in the cross section of the water path from a circular shape to the rectangular shape and vice versa. The nature of this water path is such that with the rates of flow used there is considerable turbulence within the test chamber.

Accessory equipment in each unit includes gaskets, back-up plates and clamps for holding the specimens in place. The units are fitted with hard-rubber nipples at each end in order to insulate each unit electrically from its surroundings.

The test specimens, finished with a 180-grit surface were cleaned with a wet bristle brush and powdered pumice until free from water break. They were weighed after drying and the back, edges and ⅛-inch border on the inner face were coated to prevent crevice corrosion of specimens at the specimen-test unit interfaces where they were supported. Assemblies were made water-tight by using an asbestos-type caulking compound.

Electrical connections to the test pieces were made through sharpened contact screws which passed through the insulators on the clamps and bore against the outside surfaces of the test pieces.

A saturated calomel half cell* was used as a reference electrode. It was introduced through a branch connection at the outlet of each chamber.

Electrical connections were made from the calomel half cell and the test specimen through the contact screw to a potentiometer.

An assembled test unit is shown in Figure 3.

* The saturated calomel half cell has a value of 0.246 volt referred to the standard hydrogen electrode at 25 degrees C.

TABLE I—Typical Chemical Analysis of Samples Used for EMF Potential Tests
Amount Expressed in Percentages

AISI TYPE	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Cb	Ti	Al
410	0.10	0.39	0.02	0.02	0.24	12.55	0.25	0.46	....	....	....	....
416	0.10	0.55	0.02	0.30	0.31	12.77	0.31	0.36	....	....	....	....
430	0.07	0.45	0.02	0.01	0.51	16.69	0.31	....	....	....	....	....
430F	0.06	0.71	0.02	0.31	0.39	16.13	0.70	....	....	....	....	....
431	0.15	0.59	0.02	0.02	0.43	16.75	1.76	....	....	....	....	....
303S	0.06	0.64	0.03	0.27	0.43	17.70	8.95	0.15	....	....	....	....
304	0.05	1.14	0.02	0.01	0.49	18.72	8.83	0.14	....	....	....	....
316	0.06	1.77	0.02	0.02	0.53	17.80	12.48	2.24	....	....	....	....
347	0.04	1.38	0.02	0.01	0.58	18.24	10.36	0.18	0.32	0.77	....	....
Armco 17-4 PH	0.04	0.53	0.03	0.02	0.42	16.81	4.36	0.15	3.81	0.34	....	....
Armco 17-7 PH	0.07	0.65	0.02	0.01	0.47	16.93	7.04	....	0.27	....	....	1.09
Armco 17-14 Cu-Mo	0.09	0.78	0.03	0.01	0.53	16.02	14.33	2.40	3.03	0.68	0.33	....

The tests to be described here were carried out at a rate of water flow of 10 gallons per minute per unit which was equivalent to a calculated velocity of 13 feet per second. Therefore, sea water required by the 22 test units was over 300,000 gallons per day. The sea water was unpolluted and well aerated and since it was pumped continuously there was always a fresh supply. The temperature varied between 18 and 29 degrees C with most of the tests run at 18-21 degrees C. Most of the tests lasted 15 days. These conditions were similar to those used by F. L. LaQue in determining the potentials of many other common alloys as published in 1951 Marburg Lecture, entitled "Corrosion Testing."[5]

Potential readings were taken at least once daily.

Potentials were measured with a portable Leeds and Northrup potentiometer with an accuracy of ± 0.5 mv for values over 10 mv. The calomel half cell was located 3½ inches downstream from the nearest point on the test specimen. This location of the reference electrode was chosen to give an indication of the overall potential of the whole surface of the test specimen rather than that of any possible anodic or cathodic area which might be selected in advance for such exploration by locating the tip of the half cell very close to a particular spot.

In view of the polarizing effects of even small currents (e.g., as low as 10 microamperes for certain stainless steels under these conditions of exposure) it was found desirable to avoid taking readings with the potentiometer circuit very far out of balance. The usual practice was to make a series of approximations with a galvanometer circuit closed only momentarily until the point of balance was approached. Then, the precise measurement of the steady potential value of the test piece was made.

First tests on these stainless steel samples were conducted in December and January when the sea water temperature was between 7 and 12 degrees C at a water velocity of 7.8 feet per second.

In early tests, variations in potential between duplicate specimens and among specimens of different compositions appeared to be influenced by the incidence of crevice corrosion on specimens at the point where they were held in the test unit. Consequently, an investigation of means to eliminate such effects was made.

TABLE II—Heat Treatments for Samples Used for EMF Potential Tests

Annealed Samples

TYPE	Hardness (Rockwell)	ANNEALING		
		Temp. °F	Time Hr.	Quench
303S	B83	1875	0.5	Water
304	B76	1950	0.5	Water
316	B78	2050	0.5	Water
347	B85	1950	1.0	Water
430	B87	1350	1.0	Air
430F	B96	1350	1.0	Air
Armco 17-4 PH	C35	1900	0.5	Water
Armco 17-14 Cu-Mo	B75	2250	0.5	Water

Hardened and Stress Relieved Samples

TYPE	Hardness (Rockwell)	HARDENING			STRESS RELIEVING		
		Temp. °F	Time Min.	Quench	Temp. °F	Time Hr.	Quench
410	C41	1800	20	Oil	600	4	Air
416	C41	1800	20	Oil	600	4	Air
431	C41	1925	20	Oil	600	4	Air

Hardened and Tempered Samples

TYPE	Hardness (Rockwell)	HARDENING			TEMPERING		
		Temp. °F	Time Min.	Quench	Temp. °F	Time Hr.	Quench
410	C20	1800	30	Oil	1200	4	Air
416	C21	1800	30	Oil	1200	4	Air
431	C28	1850	30	Oil	1200	4	Air

Annealed and Hardened Samples

TYPE	Hardness (Rockwell)	ANNEALING			HARDENING		
		Temp. °F	Time Min.	Quench	Temp. °F	Time Hr.	Quench
Armco 17-4 PH	C45	1900	30	Water	900	1	Air

Cold Drawn and Hardened Samples

TYPE	Condition	Hardness (Rockwell)	ANNEALING			INTERMEDIATE			HARDENING		
			Temp. °F	Time Hr.	Quench	Temp. °F	Time Hr.	Quench	Temp. °F	Time Hr.	Quench
Armco 17-7 PH	Cold Rolled	C43	....	....	.....	....	....	.....	....	....	.....
Armco 17-7 PH	Cold Rolled + Hardened	C49	....	....	.....	....	....	.....	850	4	Air
Armco 17-7 PH	Cold Rolled + Double Heat Treat.	C43	....	....	.....	1400	1	Water	900	1	Air
Armco 17-7 PH	C.R. + Ann. + Dbl. Ht. Treat.	C45	1900	0.5	Water	1400	3	Water	900	1	Air

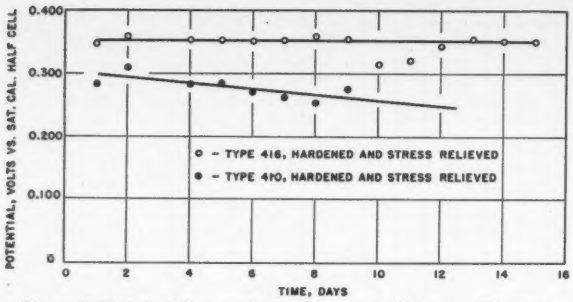


Figure 4—Effect of free machining element in 12 percent Cr steel.

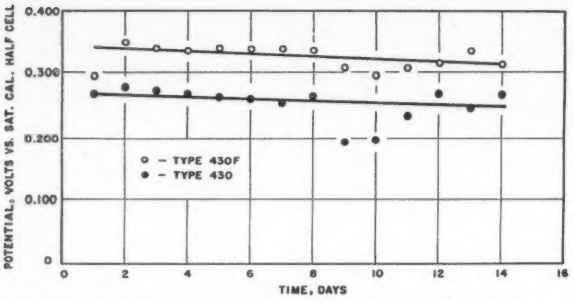


Figure 5—Effect of free machining element in 17 percent Cr steel.

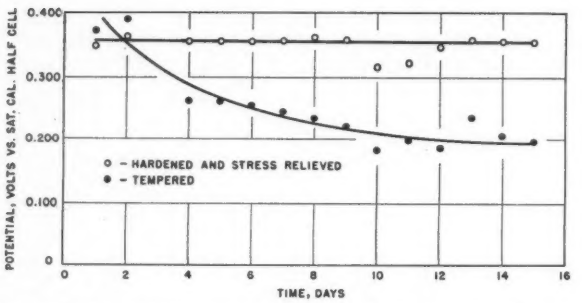


Figure 6—Effect of heat treatment of free machining 12 percent Cr steel.

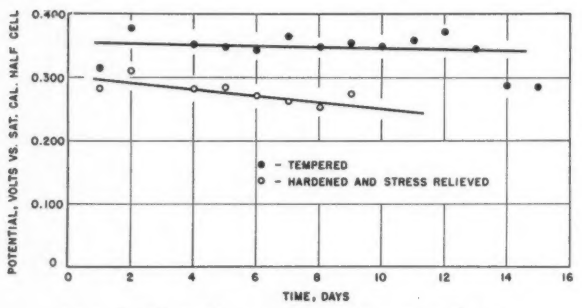


Figure 7—Effect of heat treatment of 12 percent Cr steel.

The first method studied involved mounting the sample in an air cured plastic without the application of pressure. This did not prevent attack at the leading edge because, in spite of the plastic mounting, some sort of crevice evidently existed or developed between the plastic and the metal. Samples coated with materials that had proved satisfactory for avoiding crevice corrosion in salt fog testing were not resistant to the conditions of this test. Through the courtesy of the Minnesota Mining and Manufacturing Company, samples of three types of coatings used as sealing materials in marine environments were secured. Of these, their EC-870 sealer stopped the crevice corrosion on the first group of samples on which it was used and thereby reduced the spread of potential values in the daily readings. This sealing compound was used in all subsequent tests.

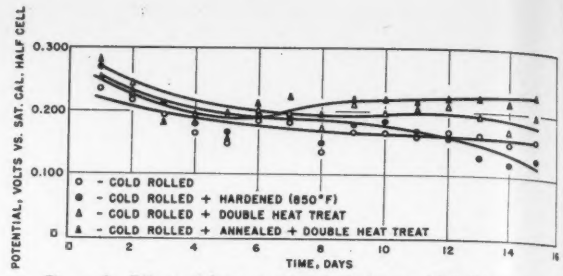

POTENTIAL, VOLTS VS. SAT. CAL. HALF CELL
0.300
0.200
0.100
0
0 2 4 6 8 10 12 14 16
TIME, DAYS
○ – COLD ROLLED
● – COLD ROLLED + HARDENED (850°F)
Δ – COLD ROLLED + DOUBLE HEAT TREAT
▲ – COLD ROLLED + ANNEALED + DOUBLE HEAT TREAT

Figure 8—Effect of heat treatment of Armco 17-7 Ph steel.

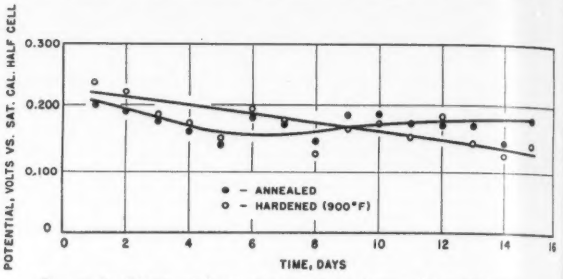


Figure 9—Effect of heat treatment of Armco 17-4 Ph steel.

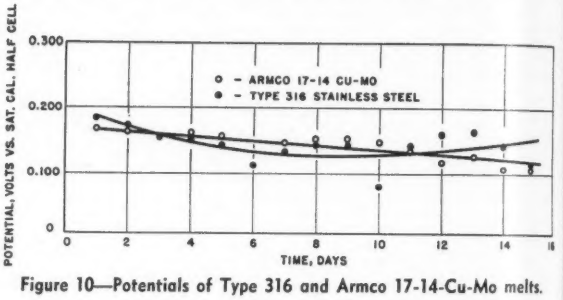


Figure 10—Potentials of Type 316 and Armco 17-14-Cu-Mo melts.

Table I shows typical chemical analyses of the various specimens used in test and Table II shows heat treatments.

The data have been summarized graphically in Figures 4 through 10. These show the effect of the free-machining element, the effect of heat treatment and the general effects of alloy content including that of certain new compositions.

It will be observed in Figure 4 that the free-machining grade with 12 percent chromium (Type 416) had a higher potential than that of the corresponding Type 410 without the free-machining element. The potential values of the two materials remained in about the same relation to one another during the entire test. From this it may be seen that the addition of the free-machining element, sulfur, in the amount of approximately 0.3 percent raised the potential of this alloy about 75 mv.

The same general condition is apparent when Type 430 (17 percent chromium) is compared with its free-machining counterpart, Type 430F (Figure 5).

The values (Figure 6) comparing the hardened and stress relieved (H & SR) heat treatment with a tempering heat treatment on Type 416 indicated that these heat treatments had a significant effect on the potential of this alloy. The tempered condition provided a more noble metal in this instance than the hardened and stress relieved condition. The overall potential difference between the two treatments amounted to approximately 100 mv.

When Type 410 was subjected to similar heat treatments (see Figure 7) the average potential values were in fairly close agreement during the early part of the test but showed a significant difference at the end of the test period. The hardened and stress relieved condition of this alloy proved to be the more noble of the two conditions studied. The average potential difference between the two treatments amounted to approximately 60 mv.

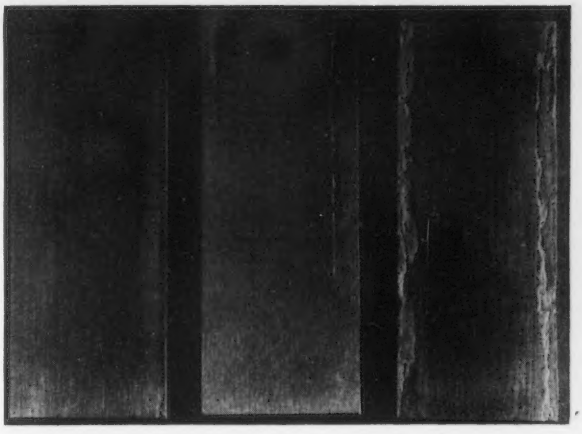
Under these testing conditions all the chromium nickel grades exhibited considerable passivity in which condition their measured potentials were very much alike.

Potential values for Armco 17-7 PH, a new precipitation hardening alloy, determined on samples subjected to four commercial heat treatments (see Figure 8) indicated that there was only a slight difference in the potential of this alloy in its several conditions. Figure 9 indicates that the same results were obtained from specimens of Armco 17-4 PH, another new precipitation hardening alloy.

Potential values were also determined for Armco 17-14 Cu-Mo, another new alloy with better general corrosion resistance than Type 316. Figure 10 indicates that these potential values were very close to those for Type 316.

It was mentioned previously that all samples had been coated in certain critical areas so as to minimize crevice attack. As these tests progressed it became evident this procedure was not wholly successful as will be seen by the samples illustrated in Figure 11. The sample of Type 410 H & SR on the left is relatively free of crevice attack; the center sample of Type 410 tempered shows moderate attack and the sample of Type 410 tempered on the right shows heavy attack.

In studying the relationship between the extent of crevice attack and the potentials observed, it appeared the principal effect was a trend towards higher potential values when crevice corrosion was most severe. This was what might have been anticipated as a result of the polarizing effect of the local action currents on the surfaces being surveyed by the reference electrode. There seemed to be less effect of the crevice corrosion on the fluctuations in the potentials themselves. Of course, it must be noted in this connection that those alloys most susceptible to crevice corrosion also tended to have higher potentials. Any direct relationship between crevice corrosion and observed potentials is somewhat obscure in that a question can be raised as to which is the cause and which is the effect.



A B C

Figure 11—Crevice attack A) KK21—Type 410 hardened and stress relieved. Free of crevice attack. B) KK24—Type 410 tempered. Moderate crevice attack. C) KK23—Type 410 tempered. Heavy crevice attack.

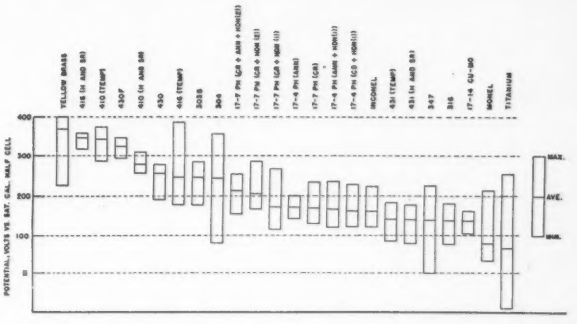


Figure 12—Galvanic series of stainless steels in flowing sea water. Flow 13 ft/sec. Temperature 18 to 29 degrees C.

Figure 12 summarizes the data gathered from these tests. The average potential and the maximum and minimum readings for each condition or grade are shown. The potential values for yellow brass, Inconel, titanium and Monel determined previously under the same conditions of test have been included in order to show the relative positions of the metals and alloys listed in a galvanic series in the form previously published.[2] It will be seen that there was about 200 millivolts spread in the average potentials of all the grades of stainless steel studied. This indicates that composition and heat treatment have a definite effect on the average potentials of stainless steels in flowing aerated sea water. While the potential values may change with different electrolyte under different conditions as to aeration, flow, etc. the relation of one alloy to another in any one electrolyte should follow this pattern. It should be realized that some conditions will exist where the maximum or minimum potential values will control. Under these conditions galvanic corrosion will be either accelerated or retarded to a greater degree.

In conclusion, these data indicate:

1. The maximum spread in the average potentials of the different grades and conditions of stainless steels is ordinarily about 200 mv in turbulent sea water. Under such circumstances, possible gal-

vanic difficulties should be anticipated when stainless steel of one composition or heat treatment is joined with another one in a galvanic couple. This is especially true where the relative area of the more noble alloy is large compared to the area of the less nobel alloy. For example, it would be unwise to use a Type 416 fastening on a Type 316 plate. The choice of such a combination would be even more hazardous under conditions involving low velocity, high temperature and opportunities for crevice attack which might occur, for example, under the head of the fastening.

2. In general, the composition of the stainless steels tested bear a general relationship to the EMF potentials in turbulent sea water. With the exception of Type 431, which showed unexpectedly noble values, the straight chromium grades had the highest average potentials; the chromium-nickel grades, including the precipitation hardening alloys, had the next highest average potentials; and the chromium-nickel grades containing molybdenum had the lowest.

3. The effect of small additions of sulfur, the free-machining element, to the alloy is unpredictable. However, it can be assumed that the addition of the free-machining element will cause an increase in the average potential of the alloy. An execption to this statement will be observed in the case of Type 416 and 410 alloys that have undergone a tempering treatment, in which case the Type 416 containing the free-machining element is more noble than its counterpart.

4. The average potentials of the straight chromium alloys were most sensitive to effects of composition and especially heat treatment which seemed to have more effect, for example, than the addition of sulfur as a free-machining element. The Type 416 alloy appeared to be more noble in the tempered condition while the Type 410 alloy showed greater nobility in the hardened and stress relieved condition.

In the case of nickel grades the differences in potential in different conditions were less. However, with the Armco 17-7 PH alloy there seemed to be some trend towards more noble potentials when hardened by cold work as compared with being hardened by heat treatment.

Acknowledgments

The writers are grateful to the managements of Armco Steel Corporation and The International Nickel Company, Inc., for permission to publish the paper; F. L. LaQue and H. T. Paterson, Jr., of The International Nickel Company, Inc., for guidance in planning these tests and for use of equipment at Harbor Island; and to A. C. Burton of the Armco Research Laboratories, Baltimore, Maryland, for preparing the test samples.

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5. Special publication, American Society for Testing Materials, Dec. 1951.

ERRATA

Prevention of Standby Corrosion in Power Plants. *Corrosion*, **8**, No. 5, 171-177 (1952) May.

Page 171, add the following footnote to the bottom of left hand column:

★ A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

Adding the omitted footnote.

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Mercury and Its Compounds—A Corrosion Hazard. *Corrosion*, **8**, No. 5, 155-164 (1952) May.

Page 162, Change footnote 2 in Table V to read:

[2] The containers were 2-inch dia. x ½-inch deep x 0.020-inch wall thickness.

Changing the third dimension to 0.020.

Isolation of Trolley Bus Negative Return to Prevent Stray Current Corrosion. *Corrosion*, **8**, No. 6, 205-211 (1952) June.

Page 209, third paragraph beginning: "To indicate .." Substitute the following for the last line of this paragraph:

similar tests in 1933 and 1921.[1]

Adding the superior figure "1."

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The Mechanism of Knife-Line Attack in Welded Type 347 Stainless Steel. *Corrosion*, **8**, No. 6, 222-223 (1952) June.

Page 222, first column, first paragraph, substitute the following for the third line:

F. stress relieving temperature for welded Type 347

Changing the letter "R" to "F."

Page 223, second column, first paragraph, substitute the line below for the third line from the bottom of the paragraph:

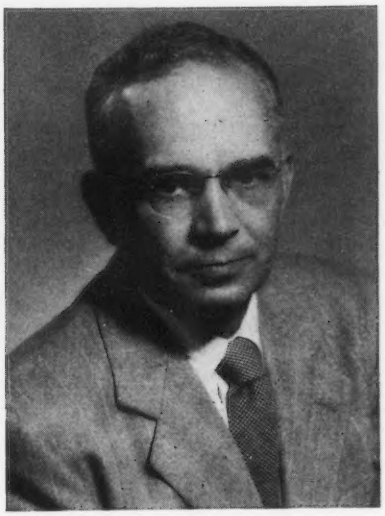
times at stabilizing temperatures are as effective

changing the word "treatments" to "temperatures."

NACE News

Five Chairmen for Chicago Meeting Named

H. L. O'BRIEN
General Chairman, 1953 NACE Conference and Exhibition at Chicago. Mr. O'Brien is product manager of Graver Tank and Manufacturing Co., East Chicago, Ind.



H. W. SCHMIDT
Technical Program Chairman, 1953 NACE Conference and Exhibition, Chicago. Mr. Schmidt is with the Materials Engineering Service of The Dow Chemical Company at Midland, Mich.

Five chairmen of symposia in the technical program for the 1953 Conference and Exhibition of the National Association of Corrosion Engineers have been named by H. W. Schmidt, Technical Program Chairman. The conference will be held at Chicago March 16-20. Mr. Schmidt also expects to designate additional symposia and symposia officials soon.

Following are symposia and officials named by Mr. Schmidt:

Cathodic Protection—Ed Doremus, Cathodic Protection Service, Houston, chairman.

High Temperature Corrosion — John Rutherford, Babcock and Wilcox Tube Co., Beaver Falls, Pa., chairman.

Protective Coatings—L. L. Whiteneck, Long Beach Harbor Dept., Long Beach, Cal., chairman; N. K. Senatoroff, Southern Counties Gas Co. of Cal., Los Angeles, co-chairman.

Oil and Gas Production—H. L. Bilhartz, Atlantic Refining Co., Dallas, chairman.

Chemical—C. A. Coberly, Mallinckrodt Chemical Co., St. Louis.

Whitney to Head 1954 Technical Program

F. L. Whitney, with the Process Section of Monsanto Chemical Company, St. Louis, Mo. has been named technical program chairman for the 1954 NACE Conference and exhibition.

New Officers Elected By Western New York Section at Buffalo

New officers were elected May 15 at the annual business meeting of Western New York Section at Buffalo. Twenty-nine members and ten guests were present. Officers elected were William O. Binder, Research Laboratories, Union Carbide and Carbon Corp., Niagara Falls, N. Y., chairman; J. E. Shields, Alox Corp., Niagara Falls, N. Y. and Paul R. Guenther, Nukem Products Corp., Buffalo, secretary-treasurer.

There also was a discussion of the 1953 Chicago meeting during which section members were asked to consider presenting papers. The Galveston Conference was discussed also and the International Nickel Co., Inc., film "Corrosion in Action" was shown.

Large Gathering Hears Liebman at Philadelphia

A large gathering including members and guests from Pittsburgh, New York and other North East Region NACE sections heard A. J. Liebman, Research Engineer, Dravo Corp., Pittsburgh and R. H. Brown, Metallurgical and Chemical Research Laboratory of Aluminum Company of America, New Kensington, Pa., at a May 9 dinner meeting of Philadelphia Section Poor Richard Club. Each talk was followed by a discussion period.

Mr. Liebman, who spoke on "Selection of Surface Preparations and Pretreatments," presented a large number of slides and photographs depicting surface preparation using various sandblasting techniques. Statistical data of results were shown in curves and tables. Mr. Liebman emphasized that no matter how effective a process may be, the important point is to correlate its use and application to a reasonable cost for the result obtained. Factors determining what surface preparation should be used include environment, expected life, use of the part protected and cost of the coating system.

Data presented by Mr. Liebman included some on stacks, buildings, bridges and fresh water barges. He also stated that recommendations to management from technical men and research scientists must include a practical way of using the recommended method at a reasonable cost.

Mr. Brown's remarks were based on the topic "Some Controlling Factors in Corrosion." Laboratory procedures were given for determining electrochemical actions and related phenomena experienced with metals. In order to correlate laboratory tests with service experience it sometimes is necessary to make the tests different from the conditions existing under service conditions, Mr. Brown said. The experimental data available on the corrosion of metals in various concentrations of acids, and under varying conditions of temperature were brought to the attention of the meeting.

Failure of heat exchanger equipment as the result of accumulation of mercury and mercury compounds in the metal was described by Mr. Brown.

NACE will pay 50c a copy for copies of MARCH CORROSION

subscribers or members find they do not need. The supply of this issue has been exhausted by the heavy influx of new association members and more copies are needed to supply others joining who want all 1952 issues.

- ***Mail copies to A. B. Campbell, National Association of Corrosion Engineers, 1061 M & M Building, Houston, Texas.***

Vast Savings From Corrosion Control Are Cited

The fight against the destructive forces of corrosion and of the great savings corrosion engineers are effecting were the subjects of a well documented paper presented to members and guests of the Detroit Section by J. F. Hirshfeld, vice president of the Hinchman Corp. L. P. Schaefer, assistant general manager of the firm was co-author of the paper.

Correlating H. H. Uhlig's figures to present values, Mr. Hirshfeld estimated that $2,000,000,000 could be saved of the direct loss each year to corrosion. What this would mean in indirect losses such as lost production would amount to much more than $2,000,000,000 he stated.

Beginning with an explanation of the simple fundamental theory of corrosion, Mr. Hirshfeld related briefly, the history of cathodic protection from the time of Sir Humphrey Davy to the present. The fundamental theory of corrosion is simple and easily understood, Mr. Hirshfeld said, but in practice, the causes and factors in corrosion are very complex. Corrosion engineers while they do not understand all of the variables involved, are able to control the destructive forces of corrosion by controlling the vital factors they do understand.

Use of electric current applied from an external source to prevent corrosion is comparatively a recent innovation brought about by the electrically powered street car and interurban, according to Mr. Hirshfeld. This "trolley car" era gave rise to the joint electrolysis committees in many cities by which utilities could cooperate to eliminate stray current electrolysis. To prevent damage to underground metal installations, engineers applied electrical drainage to underground metal installations. Some of these electrolysis committees are still quite active.

Mr. Hirshfeld stated that application of cathodic protection to buried structures was first widely exploited in the 1930's to protect oil and gas pipe lines. Use of this method spread rapidly for protection of metal structures other than pipes, above ground, under ground and in marine and water front environments. Use of cathodic protection is still in its infancy, he said.

The relation of cost of cathodic protection to savings effected is of fundamental importance, Mr. Hirshfeld related. Aside from preventing direct corrosion loss, the corrosion engineer can prevent indirect losses due to loss of production, product contamination, overdesign, loss of property and life such as caused by fire and explosion and indirect maintenance losses. For example, gas service for a certain garage could have been protected for about $1 per year. Without this protection, a leak developed. The subsequent explosion loss amounted to $100,000.

Mr. Hirshfeld stated that cathodic protection of the miter lock gates on the Panama Canal cost less than one-half of one percent of the estimated replacement cost. In another instance, one year a Southern city saved $82,000 in a replacement budget for a gas line. Cathodic protection made replacement unnecessary.

Three underground gasoline storage tanks and installation valued at $500,000 was protected by a cathodic protection installation costing $2500 and using $10 in power a year. After 10 years the tanks were in perfect condition. Heavy gauge steel piping installed in the same area without cathodic protection, pitted badly. Pits of the same depth would have perforated the tanks, Mr. Hirshfeld declared.

Estimates on the amount the U. S. Navy is saving by cathodic protection are $18 saved in repairs and replacements for every $1 spent on cathodic protection. Mr. Hirshfeld gave several other examples of how corrosion engineers are effecting great savings.

RAYMOND B. HOXENG

Newly appointed chairman of the NACE publication Committee, succeeding F. L. LaQue, resigned.

Hoxeng Named to Head Publication Committee

Raymond B. Hoxeng, with the Research and Development Laboratory of United States Steel Company, Pittsburgh, Pa., has accepted appointment as chairman of the publication committee of the National Association of Corrosion Engineers. He succeeds F. L. LaQue of The International Nickel Co., Inc., N.Y.

Mr. Hoxeng, who before joining United States Steel, was with Case Institute of Technology, has been a member of NACE since 1946 and has contributed technical material to Corrosion.

North Texas Section Hears Talk on Europe

For the last meeting before summer adjournment, the North Texas Section heard Rado Loncaric speak on "Europe —Before, During and After World War II." The subject was, of course, nontechnical. Members and guests numbered 48. The meeting was held in El Fenix restaurant.

Next meeting will be held Sept. 8.

Boston Section Renames Officers for Full Year

Officers of Greater Boston Section who were named when the section was organized in December have been reelected for a full year's term. Forty-five members and guests were present for the dinner meeting at Smith House, Cambridge. Officers continuing are Edwin J. Titsworth, Koppers Co., Inc., chairman; John Swift, Arthur D. Little Inc., vice-chairman and J. Dwight Bird, The Dampney Company, secretary-treasurer.

W. F. Fair, technical director for Koppers Company's corrosion laboratory spoke to the meeting on "Protective Coatings."

Nominations Given for North Central Region

Nominations of officers for the North Central Region for 1952 have been announced by C. E. Heil, secretary-treasurer. Jack H. LoPrete, Spray-Coat Engineers, Detroit, was nominated for chairman.

Other nominations were Norman A. Kerstein, Detroit Edison Co., vice-chairman; James F. Hershfeld, Hinchman Corp., Detroit, Mich., secretary, and Leon D. Cook, Wyandotte Chemicals Corp., Wyandotte, Mich., trustee.

Southwestern Ohio Election Results Given

Results of the election of officers for Southwestern Ohio Section were given at the May 27 meeting. Votes for the office of treasurer were evenly divided between Sylvan Falck and R. L. Wood and the board of directors is being asked to resolve the tie. Officers elected were: Roy O. McDuffie, University of Cincinnati, chairman; Arthur D. Caster, City of Cincinnati, vice-chairman; Lewis M. Lederer, Inner-Tank Lining Corp., secretary.

Mars G. Fontana, professor of metallurgy at Ohio State University and president of NACE spoke on "Recent Developments in Corrosion Resistant Alloys," to 19 members and 52 guests.

California Short Course Lectures Being Printed

Reprints of the lectures given during the University of California at Los Angeles Short Course in February are now being reproduced, according to information from the university, and copies should be mailed about July 1 to all registrants. There was a delay in printing because some speakers failed to supply corrected manuscripts.

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The Inter-Society Corrosion Committee was organized to help eliminate duplicated research into corrosion matters.

Keller Elected Head of St. Louis Section

Wayne H. Keller of Mallinckrodt Chemical Works, St. Louis was installed as chairman of the Greater St. Louis Section at a meeting May 19. Other officers installed at the same time were Otto H. Fenner, Monsanto Chemical Co., vice-chairman; Andrew T. Pickens, C. K. Williams & Co., secretary and Camden A. Coberly, Mallinckrodt Chemical Works, treasurer. Robert D. Sanford, Nooter Corp. and Howard O. Nordquist, Jos. T. Ryerson & Sons, Inc. were named board members.

There were 45 members and guests present to hear Albert MacLeod of Dow Chemical Company, Midland, Mich., talk on "Development and Application of Plastic Paints."

Mr. MacLeod gave some of the historical background of the word "plastic" as applied with paints and told why its misuse as applied to materials not classifiable as plastics had given the term a bad reputation. After defining plastic paints Mr. MacLeod cited the close relationship between the paint and plastics industries resulting from the fact the same raw materials are used by both.

He pointed to the growth of styrene production from about one million pounds in 1939 to 520 million pounds in 1950 as indicative of the vast production expansion that has occurred in a comparatively short time. The similarity of chemical structure among several major classes of plastics was pointed out.

Numerous other materials were cited and identified. In conclusion Mr. MacLeod suggested the term "plastic paints" be discarded as a misnomer and that instead the materials be called by their true names, such as, roofing cement, texture paint, styrenated oil, alkyd enamel, Saran lacquer, latex paint and so on.

Numerous samples provided by Mr. MacLeod of the various kinds of materials discussed were inspected.

Five Talk on Plastics At Los Angeles Meeting

"Use of Plastics in Corrosion Resistant Service," was the topic of five talks by speakers at the May dinner meeting of the Los Angeles Section at Rodger Young Auditorium. There were present 101 members and guests.

The five speakers and their subjects were: L. E. Tallman, Dow Chemical Co., "Use of Vinylidene Chlorides (Saran)"; L. C. Black, Plastic Process Co., "Use of Plastic Tubing and Pipe in Industry"; W. S. Shamban, W. S. Shamban Co., "Recent Developments in Polyethylene Plastics (Teflon and Kel-F)"; D. L. Trott, Haveg, Corp., "Use of Thermosetting Plastics in Chemically Resistant Equipment," and A. J. Vogel, Bakelite Corp., "Use of Vinyls in Corrosion Resistant Services."

Next meeting of the Los Angeles Section will be September 17, 1952.

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CORROSION magazine publishes information on activities involving corrosion from trade and technical groups all over the world.

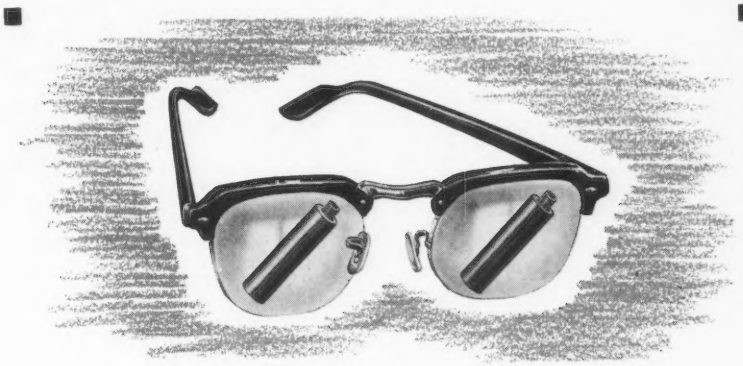
Sabine-Neches Section Elects C. A. Murray

Christopher A. Murray, Pure Oil Company, Nederland, Texas has been elected chairman of Sabine-Neches Section. He formerly was vice-chairman. Other officers elected at a May 23 meeting of the Section at Holland Hotel, Orange, Texas were Charles A. Ridenour, Magnolia Petroleum Co., Beaumont, Texas, vice-chairman and V. M. Brown, Columbia-Southern Chemical Corp., Lake Charles, La., secretary-treasurer and R. P. Clark, Atlantic Refining Co., Port Arthur, Texas, trustee to serve the reminder of 1952.

Eleven members and 10 guests were present for the meeting, the last one of the season. Ladies also participated in the cocktail hour and buffet supper accompanied by organ music. A minstrel show sponsored by the South Beaumont Lion's Club was presented.

Tulsa Section to Hear Shideler in September

Norman T. Shideler of Pittsburgh Coke & Chemical Co. is scheduled to address Tulsa Section on the first fall meeting after the summer holidays. Mr. Shideler will talk on specifications of pipe coatings from the manufacturers' and consumers' viewpoints at the meeting September 29.



Anodes look alike.....

When you are purchasing anodes, keep this in mind . . . Anodes *do* look alike. You can't tell the quality of the product you are buying, just by *looking* at it.

The life of many anodes on the market today is often shortened because of metal impurities such as nickel, iron, and copper. An impure anode *may* deliver the same electrical current output as one of high purity, but its length of service is shortened. This results in increased cost to the user because these expended anodes have to be replaced more frequently.

A careful examination of anode metal under a spectroscope quickly reveals metal impurities, making it possible to keep them at a minimum. Such tests are made here at the STANDARD MAGNESIUM laboratories every day on all anodes produced. A certified *spectrographic record* is furnished with each shipment — insuring you of the best protection at the lowest cost.

If you have a corrosion problem, we would be happy to consult with you, without obligation, at any time.

WRITE WIRE PHONE

Standard Magnesium Corporation
TULSA, OKLAHOMA

Problem of Internal Corrosion in Pipe Lines Discussed by API Group

Problems related to the internal corrosion of pipe lines were discussed at a luncheon meeting of 20 representatives of products pipe line companies during the April 23 meeting of the American Petroleum Institute Products Pipe Line Technology Committee at Fort Worth. The discussion dealt primarily with the scope of the problem and formal organization was not carried out. The discussion was reported by Ivy M. Parker of Plantation Pipe Line Company as a function of Technical Practices Committee 18-B.

Cooperative action between the National Association of Corrosion Engineers and the American Petroleum Institute was advocated. It was suggested the NACE committee undertake to collect test data and that interpretation and recommendation of standards be done by the API. The committee aim was expressed as: To seek a basis for evaluating corrosion and metal loss which would lead to a common procedure for evaluating corrosion control methods.

Criteria are Needed

Among the principal problems connected with internal corrosion of pipe lines, the discussion brought out, are the following points:

1. Measurements of Loss of Metal. Methods of determining loss of metal by inspection of test sections of pipe and through the use of test spools and coupons were held to be useful but to take too much time. J. M. Pearson of Sun oil Company described a method of electrically measuring pipe weight with the pipe in place, which permits a continuing record to be made. The objection to coupons is the question as to their relation to the actual pipe. The electrical method proposed would not show pitting.

It also was proposed that measurements might be made of corrosion products removed from the liquids running through the line. The problem here is the difficulty of collecting the material for weight measurements.

2. Study of Product Quality. With respect to scraper run data, there was some agreement with the experience of Plantation Pipe Line Company which found the stream runs black for approximately five minutes while a scraper is coming in, then appears to clear completely. Frequency of scraper runs is a factor in the amount of material brought in per scraper.

The problem was felt to be one of fine rouge, which some operators felt was less of a problem where oil-soluble inhibitors are used. Specific test results on a comparable basis are needed to properly establish this products quality factor.

Shell Oil Company's practice of running a measured volume of product through filter paper to determine the amount of rouge was mentioned. It was reported that in some cases product picked up rouge from tank trucks and terminal storage.

Other interesting data regarding products quality would be variation in rouge particle size, scraping schedule, consumption of inhibitor and water content.

3. Line Friction Measurements. It was pointed out that in order to make valid comparison among different lines it would be necessary for companies to report their data rather than a calculated "C" number.

Factors proposed by Dr. Pearson as needed for determining roughness or line friction were:

a) Length of line tested.
b) ID of line tested.
c) Elevations of test points and any higher intermediate elevation between test points.
d) Pressure drop at two or more specified flow rates.
e) Fluid density during test.
f) Fluid viscosity during test.
g) Temperature.

It was suggested also it would be well to know the age, type of line and previous service history.

R. F. Hadley of Sun Pipe Line Co. suggested subcommittees be named to work out suggested procedures for making measurements so comparisons may be made.

The committee invites suggestions as to additional measurements needed.

Corpus Christi Section Sees Transite Movie

Members and guests of the Corpus Christi Section saw a movie, "Underground Arteries," which told of the development and application of Transite pipe for underground piping. W. H. Waring of the Johns-Manville Co., came from Houston to narrate the film. John W. Nee, chairman, presided at the meeting.

Members of the section were guests of R. E. Gautreaux, plant engineer for the Celanese Corporation at a showing of the International Nickel Company's color motion picture "Corrosion in Action." The picture was shown June 12 at the Celanese Corporation's cafeteria at Bishop, Texas.

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Single copies of most back issues of CORROSION are available to NACE members at 50c each and to non-members at 75c each.

CORROSION MEETINGS

1952

Sept.
4-6—AIChE (Regional Meeting) Chicago, Ill.
8-12—Instrument Society of America Cleveland, Ohio.
10-13—Committee of Electrochemical Thermodynamics and Kinetics Cambridge University, England.

Dec.
7-10—AIChE, Annual Meeting. Cleveland, Ohio.

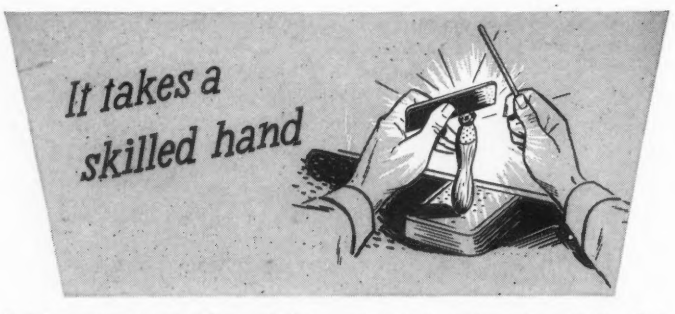
1953

Mar.
2-6—ASTM Spring Meeting and Committee Week. Detroit, Mich.

April
20-22—Metal Powder Association Cleveland, Ohio.

June
29-July 2—ASTM Annual Meeting Atlantic City, N. J.

Sept.
21-25—Instrument Society of America Chicago, Ill.



It takes patience, precision, and the highest degree of human skill to change, with a few light taps, a relatively worthless stone to a priceless gem. In the diamond cutting industry, fortunes rest on the *human equation.*

On the human equation, too, rests the efficiency of your cathodic protection system. Efficient corrosion control not only requires the use of the best equipment available, but depends on an exacting analysis of *your* problem, and design, installation and testing by top-notch specialists in the field.

Hundreds of operating installations attest to the dependability and skill of the ERP engineer. Highly trained, and backed by years of experience, he can help you solve *your* pipe corrosion problems too. E-20,

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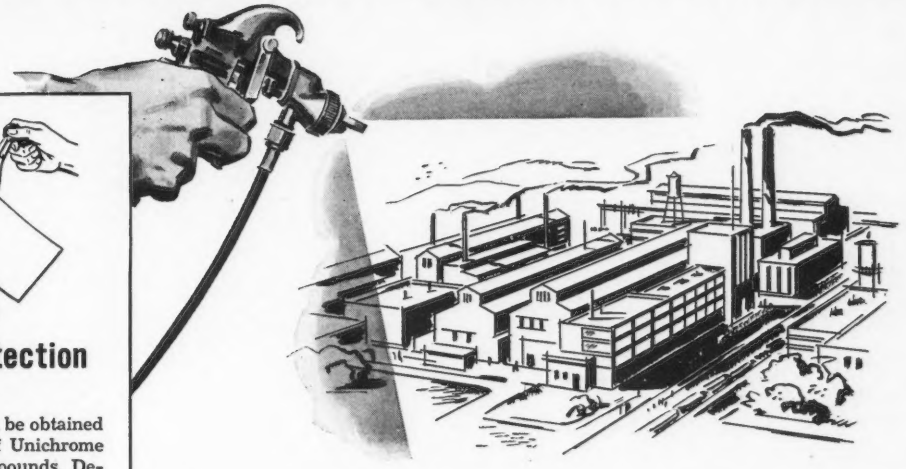
News about COATINGS for METALS

Metallic . . . . . Organic . . . . . Decorative . . . . . Protective

Preventive maintenance with UCILON* Protective Coating Systems

Gives Corrosion No Chance to Start



How to get THICKER coatings for increased protection

Coatings up to 3/16" thick can be obtained with a single application of Unichrome Plastisol or Organosol Compounds. Designed for dipping or spraying, these coatings permit you to apply heavy-duty protection to ordinary metals for use under severely corrosive service conditions.

These vinyl-base compounds resist a wide group of chemicals and corrosives. Baked at 350° F, they cure to a tough, flexible, shock-absorbing coating suitable for protecting ducts, pipe interiors, processing and conveying equipment, tanks. Write us about *your* application. We may have just the compound for it.

Drum Lining handles tough chemicals

A tremendous variety of processed products are shippable in steel drums which are lined with one of the suitable Unichrome Drum Linings. By strongly resisting chemical attack, these protective linings bar corrosion of container and contamination of the contents.

If you have a problem in packaging newly developed chemical products, or seek a tougher lining to meet your present needs, ask your drum supplier for details on Unichrome Drum Linings, or write to us directly.

Today's shortage of metals has made replacement of equipment a serious problem. Many companies are, therefore, putting greater emphasis on preventive maintenance than ever before. They have found that using chemical resisting Ucilon Protective Coatings on a regular basis avoids corrosion damage to equipment and thereby minimizes not only the need for replacement but also the costly downtime.

Unlike ordinary paints, Ucilon Coatings are based on highly chemical resistant materials. They include vinyl, chlorinated rubber, phenolic or fish oil formulations. Systems of various Ucilon Coatings have been devised with these two thoughts in mind: (1) The formation of a protective film which is an effective barrier to the particular corrosives. (2) Maintenance of adhesion and resistance to undercutting in the event of damage.

Such systems are available to deal with a "hundred and one" tough, corrosive conditions. These include intermittent or continuous contact with fumes or solutions—with acids, alkalies, salts, alcohols, moisture, oils, greases, foods, chemical compounds and other products. Some systems require baking. Most, however, dry by solvent evaporation; still others by oxidation. All are easily applied by brushing or spraying.

WHAT USERS SAY ABOUT IT

"We have yet to have a failure of any consequence in plant applications" is the way a large alkali plant puts it. The Ucilon Coatings have been extensively used for the past several years to combat corrosive atmospheres.

"Still in excellent condition after 5 years," reads another report about Ucilon Coatings applied to the interiors of brine tanks by a North Central chemical processor.

★ ★ ★

Today is no time to put up with needless corrosion of equipment, with resultant production delays, with the downtime and expense of "painting" required too frequently. You can do successful preventive maintenance as it is being done in other processing plants—where Ucilon Coating Systems, applied to equipment and plant, are giving longer lasting protection at lower cost.

Get the concise facts on Ucilon Coatings by writing for our 4-page bulletin—or look it up in your latest "C.E.C." or Sweet's Process Industries File.

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Fourth Meeting of CITCE Set Sept. 10-13

The fourth meeting of the International Committee of Electrochemical Thermodynamics and Kinetics (CITCE) will be held in England, Sept. 10-13, 1952. Site of the meetings will be in London at the Imperial Institute of Science and Technology; and in Cambridge, at Cambridge University.

Prior to the meetings, a number of laboratories specializing in electrochemistry and corrosion will be visited, Sept. 8—9.

Members of the board now holding office are: P. Van Rysselberghe, University of Oregon, president; T. P. Hoar, Cambridge University and R. Piontelli, Politechnico of Milan, vice-presidents; M. Pourbaix, University of Brussels, secretary general; and E. Lange, University of Erlangen.

Fifteen countries are represented in the membership of nearly 100. In each of these countries a national secretary attends to all matters pertaining to the activities of the committee and represents his country in the council. The national secretaries are: for Australia, A. Walkley; Belgium, M. Pourbaix; Canada, F. E. W. Wetmore; Czechoslovakia, J. Heyrovsky; Finland, R. Nasanen; France, R. Audubert; Germany, E. Lange; Great Britain, T. P. Hoar; Italy, R. Piontelli; Japan, S. Tajima; the Netherlands, W. G. Burgers; Norway, A. B. Winterbottom; Sweden, A. U. Traghardt; Switzerland, K. Huber; United States, P. Van Rysselberghe.

Previous meetings of CITCE were held in Brussels, Belgium, in 1949; Milan, Italy in 1950; and in Bern, Switzerland in 1951. Proceedings of the second and third meeting have been published and are now available. These may be ordered from Mr. Pourbaix. Cost to members of the Electrochemical Society or of the NACE is $4.80, and to non-members $6.00.

More information concerning the 1952 meeting can be had by writing Marcel Pourbaix, University of Brussels, 50 Ave. F. D. Roosevelt, Brussels, Belgium or from T. P. Hoar, Department of Metallurgy, Cambridge University, Pembroke St., Cambridge, England.

Engineering Course Centennial Planned

Plans are under way for a centennial celebration next year of the inauguration of engineering courses at the University of Michigan. A convocation on Oct. 23 and 24, 1953 will mark the opening of the centennial program.

George Granger Brown, dean of the college of engineering has appointed a faculty committee, headed by Prof. Stephen S. Attwood, aided by a five-member alumni advisory group to complete arrangements.

Plans for offering engineering courses at the University were proposed in 1837, but it was not until 1853 that the regents decided to hire Alexander Winchell to teach the courses. A course in civil engineering was inaugurated with the March, 1854 term. In 1895, a separate college of engineering was established.

BOOK REVIEWS

Atmospheric Exposure Tests of Nailed Sheet-Metal Building Materials. By Theodore H. Orem National Bureau of Standards Building Materials and Structures Report 128, 24 pages, 18 half-tone illustrations, 6 tables, Government Printing Office, Washington 25, D. C., Per Copy.....20c

To determine the resistance of nailed sheet-metal building materials to atmospheric corrosion and to point out how improper installation practices can cause serious corrosion, the NBS initiated special atmospheric exposure tests of such materials. These tests were of metallic building sheets of aluminum, aluminum alloy, aluminum-coated steel, galvanized steel, and zinc alloy exposed for two years to the atmospheres of Washington, D. C. and Hampton Roads, Virginia. This report describes the tests and gives important conclusions and recommendations concerning the installation of these materials.

Premature deterioration of a material usually results from contacts with dissimilar metallic materials of construction or from proximity to nonmetallic materials. It is often impractical to avoid using materials that may accelerate corrosion of one of two materials when they are brought into intimate contact. It is possible, however, to insulate the materials from each other by means of paints, mastics, waterproof papers, felts, etc., to minimize corrosion.

While it is not yet possible to establish the relative resistance to corrosion of the different materials because of the short duration of the tests, the corrosion of some of the materials that has already taken place because of improper installation warrants reporting on this phase of the project now.

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Electrolysis Control Handbook. (Denshoku Boshi Hand Book. In Japanese.) 466 pages, 355 figures. Edited by Electrolysis Control Research Committee (Denshoku Boshi Kenkyu Iinkai). Published by the Institute of Electrical Engineers of Japan, Tokyo, April 5, 1952. Price per copy, plus postage .....Yen 600

A thoroughly revised and enlarged edition of Denshoku Boshi Soten (Electrolysis Control Guide Book) published in 1937.

Modern theories and practices concerning electrolysis control are summarized. Practical examples and tabulated data are included to increase the value of the book to research and practical workers.

Included are statistics on corrosion damage to communication and power cables in Japan, theory of underground corrosion, analysis of stray current distribution from railways, rail bonding, railway current feeding systems, measurement of stray currents, cable sheath and pipe line currents.

Material on chemical analysis of earth, underground water and deposits on corroded metals, methods of mitigating corrosion on lead sheaths and pipe lines, cathodic protection, inhibitors, protective coverings, estimating corrosivity of underground water, and recommended specifications for cable sheaths (JEC-121A, JEC-121B, JEC-121C, April 1951).

The book also gives current governmental regulations to protect underground structures from corrosion, examples of similar regulations in other countries, such as Germany (VDE 1933), Switzerland, Britain (1920), France (1911), Spain (1900), recommendations by CCIF in Paris (1949).

Organization of the Electrolysis Control Research Committee in Japan, its members and activities also is included.

Radioisotope Tracers Check Bond Mechanism Of Porcelain Enamel

Using very sensitive radioisotope tracer techniques, scientists of the National Bureau of Standards say they have recently obtained new information on the mechanisms by which cobalt oxide in a poreclain-enamel promotes adherence of the enamel to metal.

According to NBS researchers conventional porcelain-enamel ground coats usually contain at least 8 components. The physical and chemical properties of these oxides are quite similar and the identification and quantitative estimation of small amounts of one of them in the presence of the others in such a complex system is difficult.

Studying the distribution of radioactivity in coated specimens after firing, the researchers found that a metallic cobalt layer was formed at the enamel-metal interface and that near the interface the enamel layer was depleted in cobalt oxide. The amount of cobalt that thus migrated to the interface increased with increased firing though the total quantity was extremely small—equivalent to a layer of metallic cobalt about 0.01 micron thick for normal firing. The cobalt deposit apparently did not penetrate into the enameling-iron base during normal firing.

Test Data on Asbestos Cement Pipe Compiled

Published by the National Bureau of Standards in February, 1952 and available from the Superintendent of Documents, Washington, D. C., is the following report:

RP 2264—Effect of Exposure to Soils on the Properties of Asbestos-Cement Pipe, by Irving A. Denison and Melvin Romanoff, 13 pp, 15 cents. The report summarizes results of studies on two varieties of cement-asbestos pipe for periods up to eleven years in 15 different soils ranging from well-aerated types deficient in water soluble salts to very poorly aerated soils containing high concentrations of soluble material. Effects are indicated by measuring hydrostatic bursting pressure, crushing strength, water absorption, apparent specific gravity and observations of the condition of specimen surface.

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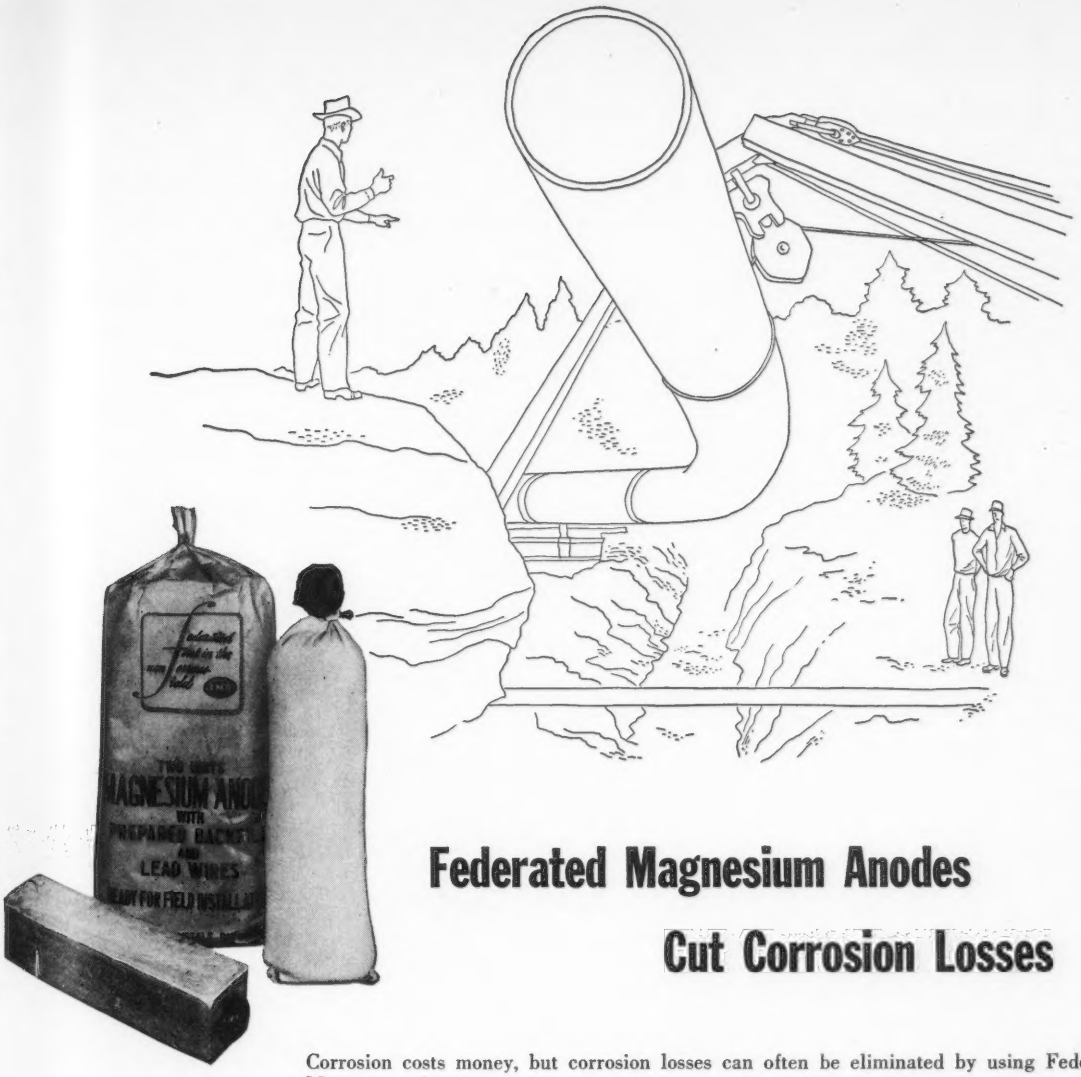
Corrosion magazine publishes information on activities involving corrosion from trade and technical groups all over the world.

•

The National Association of Corrosion Engineers now has more than 3200 members.



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Corrosion Problems

E. A. TICE, Editor

Corrosion Engineering Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Submit questions and answers for this column in duplicate to the editor. All questions become property of NACE. Questions and Answers may or may not be published under this heading, and may at discretion, be answered by mail directly. Answers to questions are solicited. Authors of questions will remain anonymous to readers while authors of answers may remain anonymous if they request it.

QUESTION

No. 48—For the sodium hydride descaling process have there been any corrosion failures of steel tanks or heat exchanger surfaces? Does steel equipment need to be annealed in order to prevent failure due to caustic embrittlement.

ANSWER

We have never had a corrosion failure of a steel tank used for sodium hydride descaling of steel. However, there have been knife edge corrosion failures of heat exchanger tubes at the air-molten sodium hydride interface. This was apparently due to the alternate oxidation of the steel (by air) and reduction (by sodium hydride) resulting from changes in the bath level. This corrosive condition was circumvented by sleeving the heater tubes with a refractory material or by leaving a sufficient air space between the sleeve and heater tube to reduce the temperature of the sleeve to about that of the bath.—Arba Thomas, Armco Steel Corp., Middletown, Ohio.

QUESTION

No. 92—A stainless steel sheet and tube heat exchanger was installed with brackish water flowing through the tubes as the cooling medium. Tube failures due to pitting necessitated retubing, and 70/30 cupro nickel tubes have been installed. Can we expect any serious galvanic corrosion between the stainless steel tube sheet and head and the 70/30 cupro nickel tubes, under continuous flow conditions?

ANSWER

No . . . based on our favorable experience in retubing stainless steel bundles with aluminum bronze tubes in hot, brackish water. Aluminum bronze and 70/30 cupro nickel are so close in the galvanic series that the performance of your material should be satisfactory.—T. F. Degnan, E. I. du Pont de Nemours & Co., Inc., Penns Grove, N. J.

QUESTIONS

No. 96—Are there any practical methods for the protection of open type high voltage (66 KV or higher) fuses against corrosion caused by the corona and atmospheric moisture?

No. 97—Have there been any investigations made regarding the effectiveness of cathodic protection of concrete coated steel pipe exposed in sea water? Will cathodic protection have any adverse effect on the bond between the concrete and the steel?

ASTM Project

American Society for Testing Materials has contracted with the Office of Defense Mobilization to develop methods for Conserving materials through the use of substitute materials or through more efficient use. Individual projects will be undertaken at the request of the recently appointed Consultant to the Director of Defense Mobilization on Conservation of Materials John R. Townsend of Bell Telephone Laboratories. Howard S. Phelps, a staff engineer of ASTM, will carry out the work. Overhead expenses will be sustained by the society and traveling and salary expenses of Mr. Phelps by ODM.

First project undertaken was on conservation of nickel, concerning which a conference of ASTM committee officers and representatives of various interested industries was held at the Philadelphia offices of the society March 11.

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Report of the Correlating Committee on Cathodic Protection. Bulletins I, II, III, IV. Per Copy, postpaid ..... $ .50

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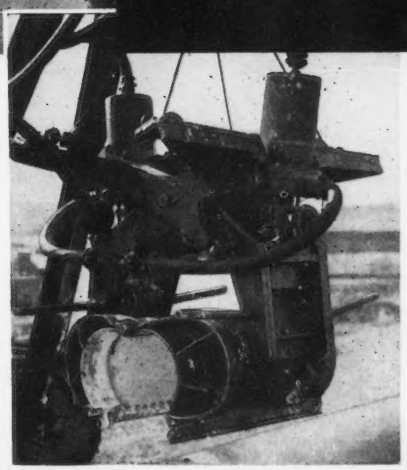

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Results of 2-Year Sheet Metal Corrosion Tests Are Given

TWO-YEAR atmospheric exposure tests of a number of sheet metals used in building construction have recently been completed by the National Bureau of Standards. Sheets of aluminum and zinc alloys and of aluminum-coated and galvanized steel were exposed to the weather under conditions closely approximating those found in actual practice. Each metal tested was fastened to bare wooden boards with nails of various materials, both with and without neoprene or lead sealing washers between the nail head and the sheet. The study was conducted by T. H. Orem of the NBS corrosion laboratory.

Severe corrosion may occur at the point of nailing if the wrong nailing is used, even with building sheet that is highly serviceable when properly installed. Although some other types of nailing will often give good service, the NBS study indicates that, in general, use of aluminum nails and carbon-black-filled neoprene sealing washers will give the greatest assurance of long trouble-free service, even under severe conditions.

The use of sheet metals in building construction has increased considerably in recent years. Factors in this include the expansion of building construction following World War II, shortages of some of the more conventional materials, and the productive capacity of the expanded metal-producing industry that became available with the relaxation of military requirements. With this increased use, adequate understanding of associated corrosion problems and of proper fastening techniques has become correspondingly important. The National Bureau of Standards has long been active in building technology investigations, as well as in studies of corrosion problems. The Bureau maintains two atmospheric-exposure test stations, one on the roof of a building on the bureau grounds at Washington, D. C., and one 10 feet over salt water near Norfolk, Virginia.

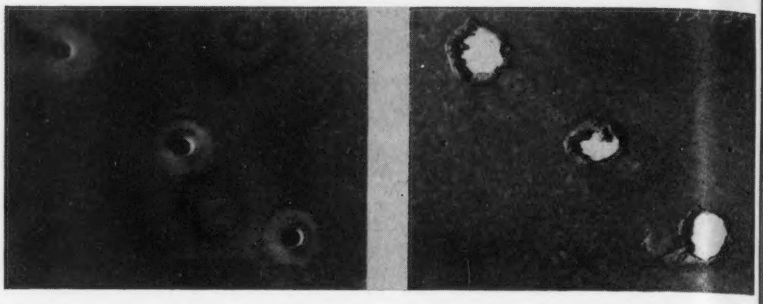

Figure 1—Typical 3 x 4 inch sheet-metal specimens after weathering in the NBS exposure tests, showing how corrosion around nail holes may result from improper nailing. Different nails were used for these two specimens; the specimens themselves, the washers under the nails and the weather exposure were all identical.

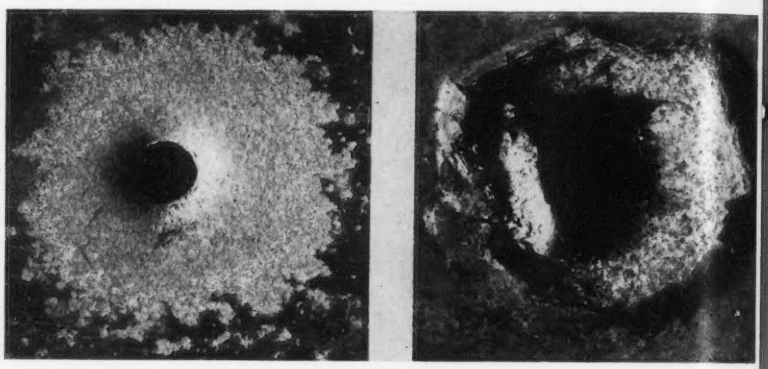

Figure 2—Close-up of a badly corroded nail hole (right) in contrast with a relatively uncorroded nail hole (left), illustrating the type of sheet-metal corrosion that can be caused by unsuitable nailing techniques. Proper nailing is particularly important with sheets of low corrosion resistance, like the one on the right; more resistant materials will not corrode so badly, even though undesirable nailing is used. (Both nail holes were the same size before the nailed specimens were exposed to weathering in the National Bureau of Standards tests. The specimens are of different sheet metals, both fastened with lead sealing washers but with different nails, both exposed 12 months in a marine atmosphere.)

Specimens Exposed Both Places

In the present NBS tests, 3-by-4-inch specimens of the various sheet metals, variously fastened, were exposed to weathering at both test stations. Nails of aluminum alloy, bare steel, cadmium-coated steel, galvanized steel and copper were used with the aluminum alloy, aluminum coated steel and galvanized sheets. Only bare steel and galvanized nails were used with the zinc-alloy sheets. Sealing washers of both regular neoprene and carbon-black-filled neoprene were investigated, as well as the more usual lead washers. In installing aluminum, good practice calls for a layer of water-resistant building paper or asphalt-impregnated felt between the metal and the wood, but in the NBS tests this protective layer was purposely omitted. Sufficient sets of specimens were exposed to permit removal of complete sets after 3, 6, 12 and 24 months and one set is being allowed to remain in the exposure racks for an indefinitely longer period.

[a] The NBS tests are reported in more complete form in the most recent of the NBS Building Materials and Structures Reports series, "Atmospheric Exposure Tests of Nailed Sheet Metal Building Materials," BMS 128, available for 20 cents from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Results of the two years' exposure clearly demonstrate the importance of avoiding certain fastening practices, particularly with aluminum. It is well established that aluminum sheet properly installed is a serviceable building material in most environments. But, as the NBS tests show, bare steel nails, or other uncoated nails except aluminum, can cause serious corrosion of the surrounding aluminum. Bare copper nails, furthermore, showed themselves to be even more corrosive than steel nails to the surrounding aluminum—a phenomenon readily appreciated by those familar with the subject, but one of which some installers of sheet aluminum have apparently been unaware. The cadmium-plated and the galvanized (zinc-coated) nails caused no corrosion while their coatings remained intact. The cadmium itself corroded away in some cases, however, exposing the steel nail and the zinc showed signs of doing so. Since the steel can begin its corrosive action on the aluminum as soon as the protective coatings have corroded away, the use of cadmium-plated or galvanized-steel nails seems questionable when maximum trouble-free life is desired from aluminum sheet. As would be expected, aluminum nails caused no corrosion of aluminum sheet in the tests.

The aluminum-coated specimens behaved similarly to the aluminum-alloy specimens at both Washington and Norfolk. Neither the galvanized nor the zinc-alloy sheets showed more than slight corrosion of any type under any condition of use. The galvanized sheets showed no corrosion from aluminum, galvanized and cadmium-plated nails and only slight corrosion from bare steel and copper nails. Similarly, the zinc alloy sheets showed no corrosion from galvanized nails and only slight corrosion from bare steel nails.

Among those familiar with corrosion theory, it is well known that when two dissimilar metals are in contact with each other, one or the other will generally tend to corrode if moisture is present. This is essentially an electrochemical phenomenon and the relative positions of the two metals in the electrochemical series generally determines which of the two will corrode.

Value of Washers Explained

Sealing washers are commonly used under the nail heads when metal building sheets are nailed and this is a highly desirable practice for several reasons. In addition to their waterproofing value, proper sealing washers reduce corrosion possibilities by keeping the nail out of contact with the sheet metal. With proper sealing washers, it therefore makes less difference what nails are

(Continued on Page 11)

Results of—

(Continued From Page 10)

used. Some washers may not continue to give a good seal, however, and in any event electrical corrosion currents may flow over the surface of the washer when moisture is present. It therefore seems advisable, where maximum sheet-metal life is important, to use suitable washers in combination with nails that would not cause corrosion even in the absence of the washers. Such conservation practice will naturally have most value under severe weathering conditions.

Carbon-black-filled neoprene washers were found to weather better than ordinary neoprene washers in the NBS tests; the latter tended to harden. Lead sealing washers caused no appreciable corrosion of specimens exposed at Washington but did cause substantial corrosion of specimens exposed in the marine atmosphere at Norfolk.

Additional exposure time will be required to establish the relative resistance of properly fastened sheets of the different metals to weathering under identical conditions. All the sheets investigated showed only very slight corrosion due to the atmosphere alone—at a distance from the nails—at the end of the two-year period.

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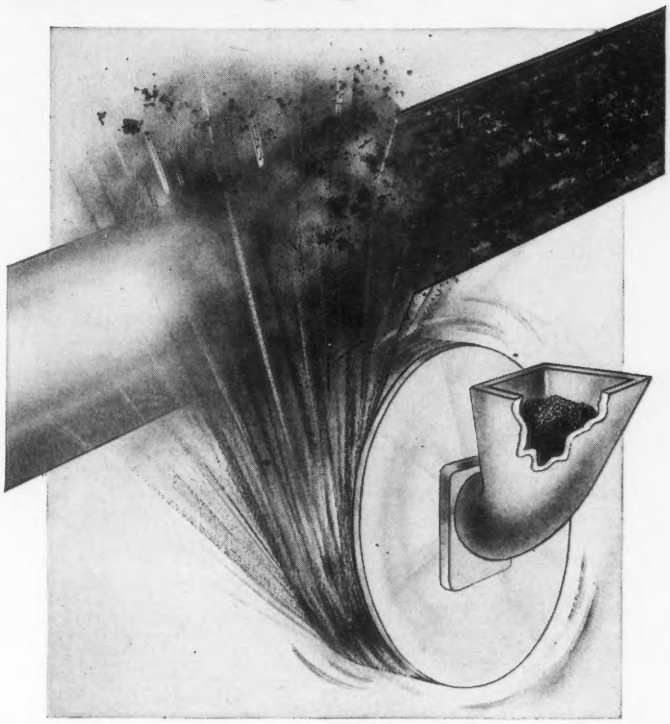
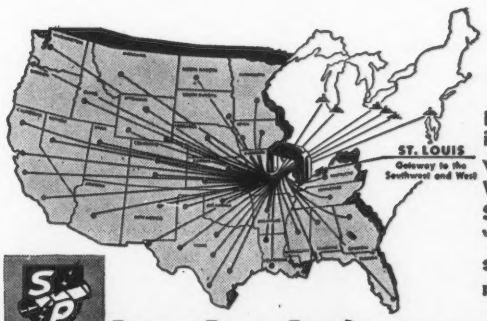


Steel grit cleaned surfaces are made up of many tiny facets, inclined toward each other at various angles, which help to key or bond the coatings to the steel. Other conventional methods of cleaning tend to polish the steel and to reduce bond. Sand blasting is only 70% to 80% as efficient... wire brushing is only 40% to 50% as efficient.



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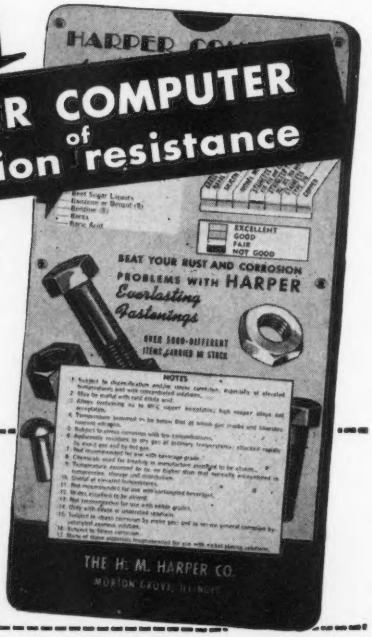

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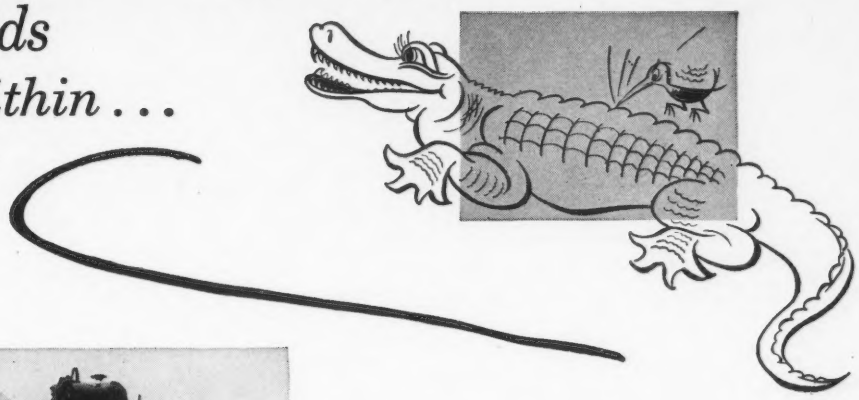

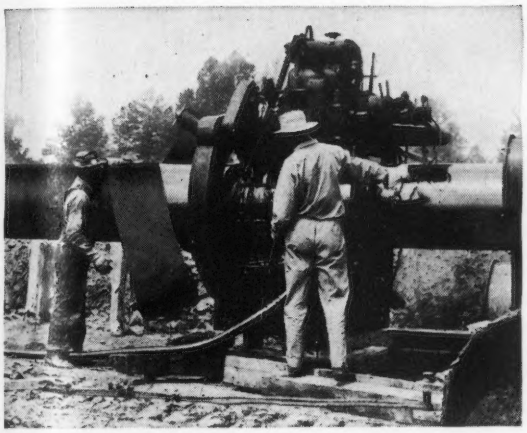

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(Continued From Page 12)

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DUBE, WILLIAM E., The Texas Company, P. O. Box 7, Harvey, La.
ELLENZ, FRED M., The Texas Company, P. O. Box 457, New Iberia, La.
GRIFFIN, JUSTIN O., Texas Eastern Gas Trans. Corp., Texas Eastern Bldg., Shreveport, La.
SIESS, CHARLES P., JR., Tretolite Co., 2509 North 12th St., Monroe, La.

MASSCHUSETTS

PERRY, LLOYD H., Union Bay State Laboratories, Inc., 491 Main St., Cambridge, Mass.

MICHIGAN

GUTTENPLAN, JACK D., Chrysler Corporation, Central Engineering, Dept. 487, 12800 Oakland Ave., Highland Park, Mich.
ABBOTT, ALBERT J., Michigan Chemical Corp., 500 N. Bankson St., Saint Louis, Mich.

MISSOURI

LEWIS, DAVID, II, Bendix Aviation Corp., P. O. Box 1159, Kansas City 10, Mo.

NEW JERSEY

EASTMAN, DOUGLAS E., Jersey Central Power & Light Co., 100 Brook Street, Long Branch, N. J.
HEINZELMAN, EDWARD, JR., 276 8th St., Palisades Park, New Jersey.

NEW YORK

BISHOP, CLAUDE R., Union Carbide and Carbon Research Lbs., 4625 Royal Ave., Niagara Fall, N. Y.
COLLOPY, WILLIAM J., Nukem Products Corp., 111 Colgate Street, Buffalo 20, New York.
FINCH, LAWRENCE NELSON, II, Berlin & Jones Co., Inc., 601 West 26th St., New York 1, N. Y.
WILEY, J. P., Esso Shipping Co., 30 Rockefeller Plaza, New York 20, N. Y.

NORTH CAROLINA

KRIEK, P. PAUL, American Enka Corporation, Enka, North Carolina.

OHIO

KING, RAYMOND W., The Special Screw Products Co., 5445 Dunham Rd., Bedford, Ohio.

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THURMAN, R. G., Panhandle Eastern Pipe Line Co., Box 59 Maumee, Ohio.

OKLAHOMA

CARLBERG, BOB L., Continental Oil Company, Drawer 1267, Ponca City, Okla.

OREGON

MANGOLD, ALFRED O., Pacific Power & Light Company, Public Service Bldg., 920 S. W. 6th Avenue, Portland 4, Ore.

PENNSYLVANIA

MAIER, R. WILLIAM, Coatings Engineers, 2006 First National Bank Bldg., Pittsburgh 22, Pa.
MERCER, ROBERT S., Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 1, Pa.
REED, GEORGE, American Car and Foundry Company, 9th and Oak Streets, Berwick, Pennsylvania.

RHODE ISLAND

ANDREWS, GEORGE E., The Narragansett Electric Co., Eng. Div., 49 Westminster St., Providence 1, R. I.

SOUTH CAROLINA

BARKLEY, MATTHEW B., Southern Corporation, Box 810, Charleston, S. C.

TENNESSEE

WALKER, SOLON, East Tennessee Natural Gas Co., P. O. Box 831, Knoxville, Tenn.

TEXAS

BALLARD, JOSEPH W., Boyd Industrial Engineering, Inc., 718 N. Stonton, El Paso, Texas.
BOWMAN, WILLIAM W., Armco Drainage & Metal Products, Inc., P. O. Box 1699, Houston, Texas.
DAVIS, EDWARD C., JR., Western Industrial Maintenance, Inc., 2207 Nicholson, Houston, Texas.
EDWARDS, WM. H., The Superior Oil Company, 400 Oil & Gas Building, Houston, Texas.
FITZGERALD, CHARLES L., JR., Maintenance Engineering Corp., P. O. Box 2637, Houston, Texas.
HISKEY, C. G., Armco Drainage & Metal Products, Inc., P. O. Box 1699, Houston 1, Texas.
HOPWOOD, WILLIAM A., Tnemec Co., Inc. 2718 Walnut Ave., Odessa, Texas.
GRONINGER, CLARK R., Oil Recovery Chemicals, 705 Lamar Blvd., Austin, Texas.
JONES, DARRELL M., Columbia-Southern Chemical Corp., P. O. Box 4026, Corpus Christi, Texas.
LIPSCOMB, THOMAS G., II, Humble Oil and Refining Co., Research Bldg., Baytown, Texas.
OSLIN, J. A., 740 Harriot Street, Beaumont, Texas.
SHAY, NEIL E., The American Brass Company, 1205 Irwin-Keasler Blvd., Dallas 1, Texas.
SIMMONS, EDWARD J., Sun Oil Company, 1405 No. Zangs Blvd., Dallas 3, Texas.
SINGLETON, WALTER T., JR., Boyd Industrial Engineering, Inc., 718 N. Stanton St., El Paso, Texas.
WARDEN, ROBERT L., Shell Oil Co., Box 3832, Odessa, Texas.
ZUSPAN, GEORGE W., E. I. du Pont de Nemours & Co., P. O. Box 2027, Orange, Texas.

WASHINGTON

ADAMS, MARK F., Division of Industrial Research, State College of Washington, Pullman, Washington.
SMITH, ROY H., Boeing Airplane Co., P. O. Box 3107, Seattle, Washington.
SUMMERSON, THOMAS J., Kaiser Aluminum & Chemical Corp., P. O. 1451, Spokane, Washington.

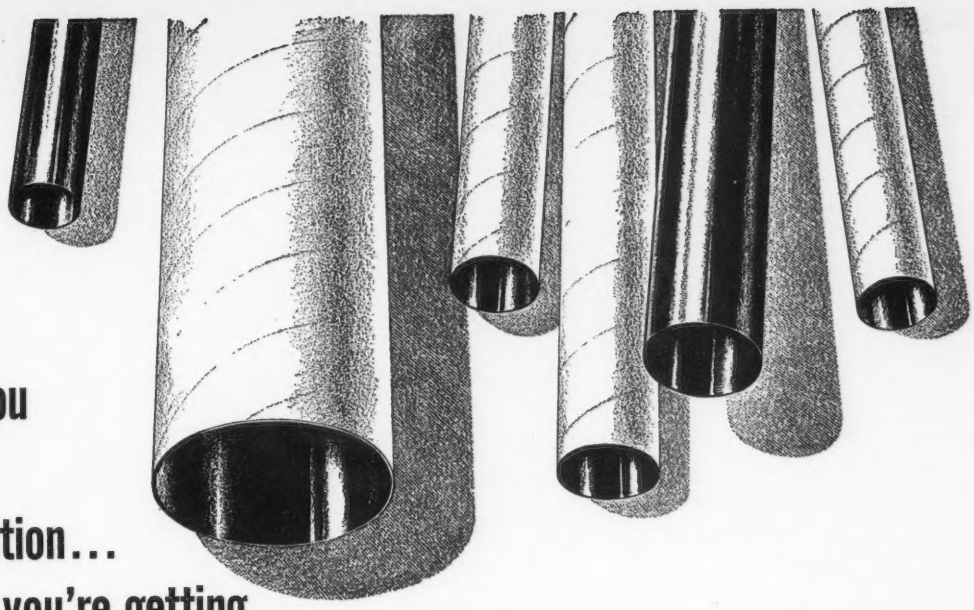
WEST VIRGINIA

BUSH, RICHARD T., Carbide and Carbon Chemicals Company, P. O. Box 2831, Charleston, West Virginia.

FOREIGN

McPHERSON, GEORGE M., Imperial Oil, Limited, 300—9th Avenue West, Calgary, Alberta, Canada.
CORBETT, R. E., Minnesota Mining & Manufacturing of Canada, Ltd., P. O. Box 757, London, Ontario, Canada.
McCOPPEN, W. J., Minnesota Mining & Mfg. of Canada, Ltd., Box 757, London, Ontario, Canada.
LAW, R. J., The International Nickel Company of Canada Ltd., 25 King St., West Toronto, Ontario, Canada.
NADAS, MICHAEL C., Corrosion Service Limited, 77 York Street, Toronto, Ontario, Canada.
ORR, ROY A., Noranda Copper & Brass Ltd., 29 Park St. W., Windsor, Ontario, Canada.
GAINES, PAUL, International Petroleum (Colombia), Limited, c/o Intercol Barrancabermeja, Colombia, S. A.
BROWN, SELWYN, John Dale, Ltd., Brunswick Park Road, New Southgate, London N. 11, England.

(Continued on Page 16)



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New Members—

(Continued from Page 14)

FLORES, LIBRADO, Mexican Zinc Co. S. A., Apartado 89, Nuevo Laredo, Tamps., Mexico.

ADROVER, ANTONIO VICENS C. A. La-Electricidad de Caracas Calle Marron a Pelota No. 8 Caracas, Venezuela.

CHANGES OF ADDRESS

(Old Address Follows New in Parentheses)

ARKANSAS

SHAW, A. G., Ebasco Services, Inc., P. O. Box 2899, Little Rock, Arkansas (Ebasco Services, Inc., Const. Dept., 2 Rector Street, New York, N. Y.)

CALIFORNIA

BIREN, JACK A., Continental Oil Co., P. O. Box H, Seal Beach, California (The Texas Company, P. O. Box 320, Long Beach 1, Cal.)

FOX, ARTHUR R., 1833 Berryman St., Berkely 3, California (Corrosion Engineering Service 3405 Piedmont Avenue, Oakland, Cal.)

McCOMAS, JOHN Q., Parker Engineering Co., 7044 E. Bandini Blvd., Los Angeles, Cal. (P. O. Box 1078, Beverly Hills, Post Office Beverly Hills, Cal.)

NICHOLSON, JAY T., National Aluminate Corp., 3023 West Pico Blvd., Los Angeles 6, Cal. (425 South Western Avenue, Los Angeles 5, Cal.)

CONNECTICUT

RASMUSSEN, LAURENCE M., Manning, Maxwell & Moore, Inc., 250 E. Main St., Stratford, Connecticut (11 Elias St., Bridgeport 2, Conn.)

GEORGIA

ROSSELLE, DOUGLASS T., Southern Bell Tel. & Tel. Co., 1432 Hurt Bldg. Atlanta, Georgia (36 N. E. Second, Miami, Fla.)

ILLINOIS

HOLSINGER, FRED J., Corn Products Refining Co., Chem. Div. Box 345, Argo, Cook Co., Ill. (Corn Products Refining Co., Argo, Cook Co., Ill.)

KOPPL, FREDERICK, James G. Biddle Co., 20 West Jackson Blvd., Rm. 602, Chicago 4, Ill. (American Institute for Foreign Trade, P. O. Box 191, Phoenix, Ariz.)

KANSAS

JOHNSTON, THOMAS A., JR., Aluminum Co. of America, 1011 Central Bldg., Wichita 2, Kans. (Aluminum Ore Co., P. O. Box 1346, Mobile 8, Ala.)

ROGERS, FREDRIC H., 2017 W. Laurel St., Route 3, Independence, Kans. (Great Lakes Pipe Line Co., Bryant Bldg., Kansas City, Mo.)

LOUISIANA

DONNELLY, PATRICK R., 622 Stevenson, Apt. 5, Lafayette, La. (Box 686, Smithville, Texas).

GALENNIE, ERNEST S., JR., 277 Wainwright Drive, Route 2, New Orleans 21, La. (Metal Goods Corporation, 432 Julia Street, New Orleans, La.)

NELSON, L. A., Jr., Freeport Sulphur Co., Little Caillou Rte., Box 555, Houma, La. (Freeport Sulphur Co., P. O. Drawer 'A', Freeport, Texas)

MISSOURI

KIMMEL, ALBERT L., Tnemec Co. Inc., 123 W. 23 Ave., North Kansas City 16, Mo. (Engr. & Ind. Exper. Sta., University of Florida, Box 2368, University Sta., Gainesville, Florida).

NEW YORK

ERGÜL, NECDET F., 276 Read Ave., Crestwood, Tuckahoe 7, New York (Long Island Lighting Co., 250 Old Country Road, Mineola, Long Island, N. Y.)

De LASKI, ROBERT D., Pittsburgh Coke & Chemical Co., 350 5th Ave., New York 1, New York (W. A. Briggs Bitumen Co., 30 Church St. 423 E., New York 7, New York)

HALL, NATHANIEL, 239 Waverly Ave., Brooklyn 5, New York. (G. B. Hogaboom, Jr. & Co., 44 East Kinney St., Newark, New Jersey)

SILKWORTH, GEORGE H., 37-09 75th St., Jackson Heights 72, New York (Ebasco Services, Inc. 2 Rector St., New York, N.Y.)

OHIO

COATS, HARRY P., 414 N. Firestone Blvd., Akron, Ohio, (Firestone Steel Products Co.)

GOODWIN, JAMES M., 722 Maryland Ave., Lancaster, Ohio. (Texas Eastern Tran. Corp., Somerset, Ohio)

McGLOTHLIN, BRUCE B., JR., 98 Brighton Drive, Akron, Ohio. (564 Delaware St., Buffalo, N. Y.)

MICHAEL, LEWIS E., 45 Woodcrest Ave., Dayton 5, Ohio. (31 So. Willow Grove Ave., Dayton 9, Ohio).

OKLAHOMA

NORRIS, R. J., Koppers Company Inc., Tar Prod. Div., P. O. Box 1074, Tulsa, Oklahoma (122 So. Michigan Ave., Chicago 1, Illinois).

PENNSYLVANIA

DAUGHERTY, JAMES G., Sun Pipe Line Co., 1608 Walnut St., Philadelphia 3, (Susquehanna Pipe Line Co.)

GALLUP, DUDLEY D., G. O. Carlson, Inc., P. O. Box 190, Bala Cynwyd, Pennsylvania (Thorndale, Pennsylvania)

SHEPPARD, WALTER LEE, JR., 9500 Martan Road, Phila. 18, Pa. (Electro-Chemical Engineering & Mfg. Co. 750 Broad St., Emmaus, Pa.)

YOUNG, FRANK A., Sun Pipe Line Co., 1608 Walnut St., Philadelphia 3, Pa. (Susquehanna Pipe Line Co.)

TEXAS

CASTILLA, RALPH A., Vinson Supply Co., 3331 Haggar Dr., Dallas, Texas (Reynolds Metals Co. 3008 Almeda, Houston, Texas)

CONNELLY, LEWIS B., Tennessee Eastman Co., 1001 State National Bldg., Houston 1, Texas (2005 Continental Bldg. St. Louis 1, Mo.)

ELLWOOD, EDWARD E., Reynolds Metals Co., P. O. Box 8176, Houston, Texas (4144 Lindell Ave., St. Louis 8, Mo.)

FENWICK, DICK T., Southern Production Co., Inc., P. O. Box 670, Fort Worth, Texas (P. O. Box 1780 Shreveport, La.)

GARTNER, FRED W., JR., F. W. Gartner Company, Box 1303, Houston, Texas (3005 Lamar).

KLINGER, O. C., The Pipeliner, 101 West Alabama, Houston 6, Texas (Oildom Publishing Co., 1217 Hudson County Blvd. Bayonne, New Jersey)

MULLINS, JOHN D., Union Sulphur & Oil Corp., 4th Floor Bank of Commerce Bldg., Houston 2, Texas (663 Gulf Bldg.)

WATTS, JOHN C. JR., Humble Pipe Line Company, Box 1390, Midland, Texas (P. O. Drawer 2220, Houston, Texas)

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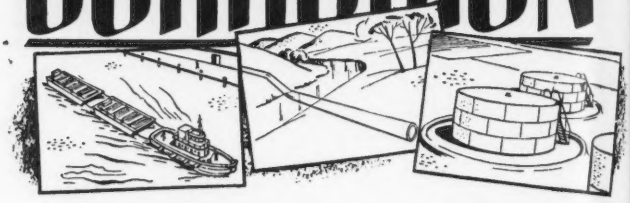

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NEW PRODUCTS —Materials—Service—Literature

Quaker Oats Co. plans to build a $600,000 addition to its furfural manufacturing facilities in Memphis, Tenn. Much of the equipment will be out of doors with only those parts which must be protected from the elements housed inside. It is claimed the installation at Memphis will be the first in the world to utilize the continuous procedure in the manufacture of furfural alcohol. It is based on work by A. P. Dunlop, assistant director of chemical research for the company and his associate, Samuel Swadesh.

•

"Neelium," a new liquid Neoprene solution for use as an industrial maintenance coating produces a high quality coating of maximum thickness with a minimum amount of labor, according to the manufacturers, Atlas Mineral Products Co., Mertztown, Pa. The Neoprene base paint with a solids content of greater than 60 percent has excellent resistance to acids, alkalies, oils, aliphatic hydrocarbons, sunlight and weathering, the company states. Corrosion resistance is excellent, it is claimed.

•

The Winner Manufacturing Co., Inc., Trenton, N. J., has released a new 12-page, two-color booklet describing its products. The firm makes, among other things, corrosion resistant containers, laminated and metal products.

•

Barrows Porcelain Enamel Co., Cincinnati, Ohio has prepared a guide to the use of metals suitable for ceramic coatings in industrial installations. The company claims that by following the suggested maximum temperatures listed in the guide, intergranular corrosion and rupture or failure due to fatigue strains at high temperatures can be avoided.

•

Apex Metal Products Corp., Cleveland, Ohio announces it has acquired an exclusive license for the continuous casting of aluminum and all other nonferrous metals. The firm states that production of bar stock for screw machine and forging operations involves no intermediate forming whatsoever and represents the shortest possible distance from molten metal to the screw machine or forging hammer. The firm states that present procedures involving rolling or extrusion limit the make-up of the alloy which can be used, and that the new process removes this limitation.

•

The Superior Tube Co., Norristown, Pa., has issued some brief pointers on the heat treating of austenitic alloys. Short paragraphs are devoted to: Carbide Precipitation in Temperature Range 900-1600° F., Thin Oxide of Chromium Formation with Alloys Above 12% Chromium, Absorption of Carbon at Elevated Temperatures, Zinc Embrittlement If Annealed After Contamination, and Stress Corrosion Cracking.

•

A warm air furnace humidifier made entirely of porcelain enameled steel to prevent corrosion and to facilitate cleaning has been introduced by the Bettinger Corp., Waltham, Mass. The humidifiers are designed for home use.

•

The Babcock & Wilcox Co., Beaver Falls, Pa. has issued a new data card which outlines uses of seamless cold-drawn carbon steel mechanical tubing for the production of hollow precision parts. The firm claims savings in time and costs through the use of its products.

•

The Wilbur & Williams Co., Brighton, Mass. is publisher of a brochure on its product, "Odor-Less Dampcoat Enamel." The company says that by mixing white enamel with six "Deep Tone Colors," practically any color can be obtained.

•

Aurand Manufacturing & Equipment Co., Cincinnati, Ohio, is marketing a light, compact, portable cleaning tool which it claims will remove the most tenacious scale, old paint, rust or foreign matter from iron, steel, brick or concrete. The tools are either electric or pneumatic powered. Cleaning action is produced by a revolving set of toothed cutters which strike the surface to be cleaned. The impact produced by centrifugal force is limited by an adjustable depth shoe, preventing damage to the permanent surface.

•

Bart-Messing Corp., Belleville, N. J. has developed a rectifier which is sealed off from all outside air. Water is used as a cooling agent and the cooling unit is sealed in the cabinet along with the transformers and selenium stacks. A fan circulates the sealed-in air over copper tube aluminum-finned water circulation coils. The trapped air does not exceed 95° F at any time. The firm will build completely sealed rectifiers in any size.

•

Royston Laboratories, Inc., Blawnox, Pa., has established a warehouse in Tulsa, Okla., to supply Western and Mid-Western customers. Included among products to be warehoused in Tulsa are "Roskote," cold-applied pipe mastic; "Royston Glas-Wrap"; "Roskote" quick-drying shop coats and "Roylac" Aluminum.

•

Allen Cathodic Protection Company, to be known as All-Co, located at Harvey, La. across the Mississippi River from New Orleans offers complete cathodic protection service, including design, surveys, installation and all types of material and supplies. Magnesium anodes will be stocked at the firm's warehouse. Henry W. Allen, formerly with Cathodic Protection Service, is organizer of the new firm.

•

American Chemical Paint Co., Ambler, Pa., is marketing Alodine, a surface conversion coating for aluminum and aluminum alloys. According to the company its "Alodizing" process is an electroless protective surface conversion process for bonding paint to aluminum and protecting the metal. The firm claims the product is superior even to anodic oxidizing. Alodine can be applied by immersion, spraying, flow coating or brushing.

PERSONALS

Ransom Cooper, Jr. has been appointed manager of the Nickel Sales Department and **H. D. Tietz,** manager of the Inco Nickel Alloys Department of the International Nickel Co., Inc. Paul D. Merica, president announced the appointments. Mr. Cooper has been with International Nickel since 1929. He was assistant sales manager of the Nickel Sales Department for a number of years. Mr. Tietz joined International Nickel in 1931 as a salesman. In 1939 he was appointed administrative assistant to the sales manager of the Inco Nickel Alloys Department. His entire career has been in the field of metal sales.

•

Albert W. Smith has joined Ebasco Services Inc., as advertising and sales promotion consultant. Mr. Smith was formerly sales promotion and advertising manager of Arizona Public Service Co.

•

Three changes in the sales and management staff of Dowell Incorporated have been announced by A. C. Polk, Jr., General Manager of the organization. **R. D. Shaw** has been named director of sales. Mr. Shaw has been with Dowell since the company was organized in 1932. Marshall Stirling will move from Ft. Worth to Tulsa to take over the post of general sales manager. Named to head a newly organized department is W. N. Estell of Tulsa. As assistant general manager of Dowell, Mr. Estell will institute and direct the company's employe-public relations department.

•

William H. Worrilow, Sr., president of the Lebanon Steel Foundry, Lebanon, Pa., spoke in Schaffhausen, Switzerland at the dedication in May of the Fischer Library, an international library devoted to the history of iron and steel.

The library is named after Johan Conrad Fischer, Swiss ironmaster who founded 150 years ago, George Fischer Ltd. The Lebanon Steel Foundry has a patent arrangement with the Swiss company.

The library's 8000 volumes include fine printed books and manuscripts from the 13th to the 18th century. There are many classics on the subject of iron, such as the works of Biringuccio, Agricola, Blumhof, Hassenfratz, Swedenborg and J. Beck. Scholars from throughout the world are invited to visit the library and conduct research at no cost.

•

Elliot C. Bacon has been named assistant manager of Solar Aircraft Company's Research Products Division, Edmund T. Price, president and general manager, announced recently. The company is principally a producer of aircraft jet and piston engine components. However, as a result of research, the firm also markets ceramic coatings for high temperature metal use, stainless steel castings and back-up fluxes for fusion welding of steels.

•

Sol M. Gleser, in charge of corrosion

(Continued on Page 19)

PERSONALS

(Continued From Page 18)

investigations of the Upper Mississippi Division, Corps of Engineers, U. S. Army, has been cited for Meritorious Civilian Service. The citation, signed by Lt. Gen. Lewis A. Pick, Chief of Engineers, U. S. Army, stated that "Mr. Gleser's initiative and untiring efforts in the study of various protective coating materials and methods of application enabled him to render invaluable technical advice and assistance in preparing a paint manual and guide specifications which will benefit the entire Corps of Engineers resulting in a substantial savings in manpower, time and materials." Mr. Gleser is a member of the National Association of Corrosion Engineers.

•

Thomas D. Cartledge has been appointed president of Linde Air Products Co., a Division of Union Carbide and Carbon Corp. Mr. Cartledge has been senior vice-president of Linde Air Products Co., and a director and vice-president of Dominion Oxygen Co., Ltd., a Union Carbide subsidiary. Mr. Cartledge entered the firm as a salesman. He was district manager in Kansas City, and later held the same post in Dallas. In 1925 he was transferred to Linde's general sales management staff in New York, and later became Manager, Gas Sales. He has also held positions as assistant general sales manager, general sales manager, vice-president, senior vice-president, director and a member of the executive committee of Linde Air Products Co.

•

Howard S. Bunn has been appointed President of Bakelite Co., a division of Union Carbide and Carbon Corp. Mr. Bunn entered the Carbide organization in 1922 as a salesman. Other positions he held with the firm were: advertising writer; advertising manager, manager of the Pyrofax Division, and manager of the Plastics Division of Carbide and Carbon Chemicals; vice-president, Plastics Division of Carbide and Carbon Chemicals Co., and vice-president in charge of sales, Thermoplastics Division of Bakelite Co. He is a director and vice-president of Bakelite Co. (Canada); a director of Bakelite Ltd. (England); a director and vice-president of Canadian Resins and Chemicals Ltd., and a director of U. S. Testing Co.

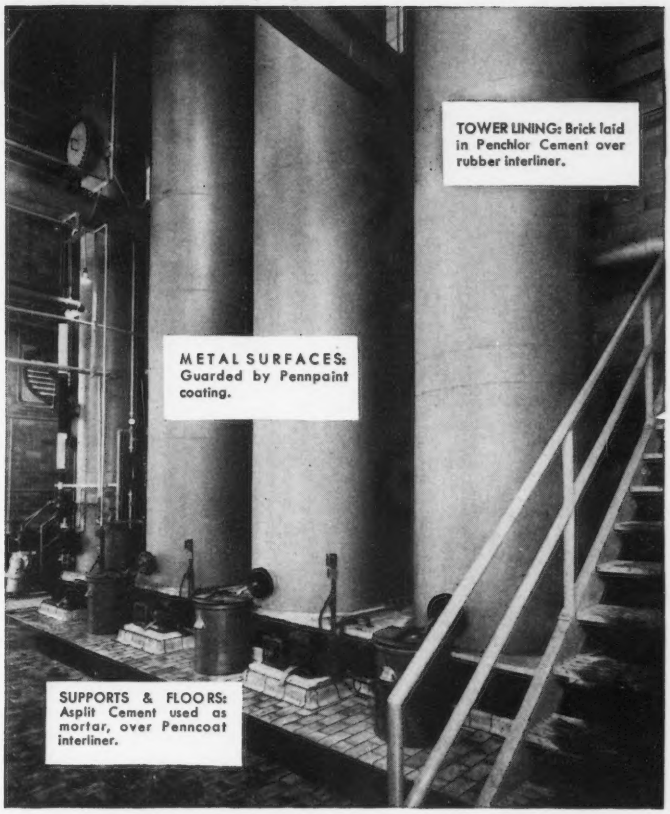
•

Walter W. Edens has been appointed to the sales engineering staff of the Federated Metals Division, American Smelting and Refining Co. Mr. Edens will be concerned primarily with the foundry trade. Before coming to Federated, Mr. Edens worked in an executive capacity with the Heil Co., and with Ampco Metal, Inc., as chief metallurgist and foundry superintendent. He is a member of the American Society for Metals and American Foundrymen's Society. He holds a master's degree in metallurgy from the University of Wisconsin.

•

Octagon Process Inc., manufacturer of metal finishing and metal cleaning compounds, Staten Island, N. Y., has appointed Paul Mezick district sales manager for Pennsylvania.

CORROSION-PROOFED BY PENNSALT


TOWER LINING: Brick laid in Penchlor Cement over rubber interliner.
METAL SURFACES: Guarded by Pennpaint coating.
SUPPORTS & FLOORS: Asplit Cement used as mortar, over Penncoat interliner.

For 13,200 hours . . . this room has handled H_2SO_4 saturated with chlorine

This room is a good example of Pennsalt anti-corrosion know-how. It is *our own room*, protected by Pennsalt products, at our Wyandotte, Michigan, plant.

Notice the "new" look about this room—despite the fact that for a year and a half it has been continuously handling highly corrosive sulfuric acid saturated with chlorine.

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Thorough-going research, plus many years of sales-engineering experience, combine to offer you 15 different corrosion-resistant cements, as well as paints, to meet your needs. From the floor to the top of your smokestack, we can offer you qualified counsel and job-proved products to lick the problem. Write: Corrosion Engineering Products Department, Pennsylvania Salt Manufacturing Co., Phila. 7, Pa.

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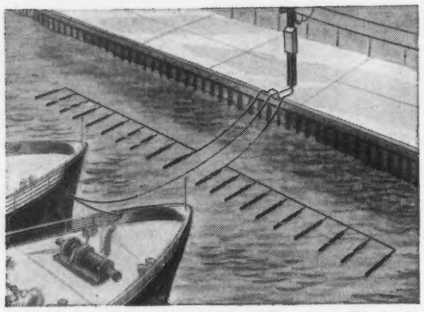
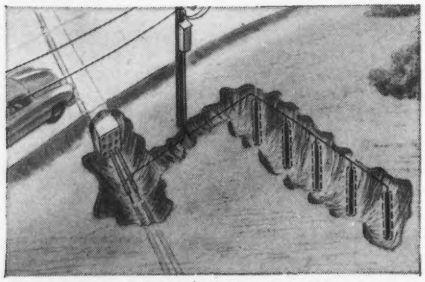
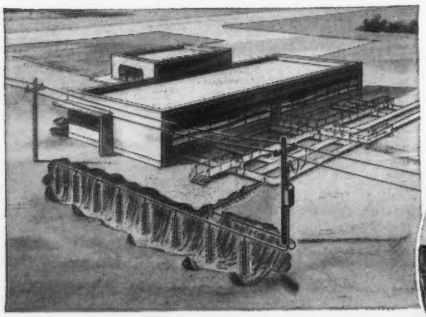
STOP it with NATIONAL TRADE-MARK Graphite Ground Anodes



SHIP HULLS — Inactive ship hulls are effectively and economically protected with remotely located "National" Ground Anodes. Active vessels also can be protected with anode plates mounted on or near the bilge keel.



LEAD-COVERED CABLES — Both telephone and power cables are cathodically protected in many areas with "National" Anodes.



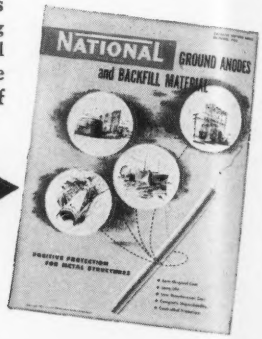
PIPE-LINE BOOSTER STATIONS — In most cases the underground structure of a pipe line booster station, which represents a large monetary investment, can be protected by a single, inexpensive bed of "National" Ground Anodes.

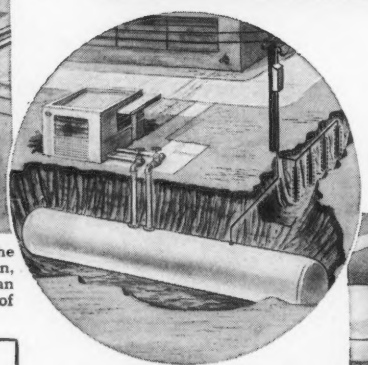
You can do much more than *arrest* corrosion. You can *eliminate it completely* — at a fraction of the cost of maintenance and replacement — with cathodic protection, employing "National" Graphite Ground Anodes.

Proved and widely accepted for the protection of steel and cast-iron pipe lines, cathodic protection is finding new applications every day in the scores of industries that otherwise must continue to pay their share of the terrific toll levied against metal structures by soil, air, water and dissolved minerals.

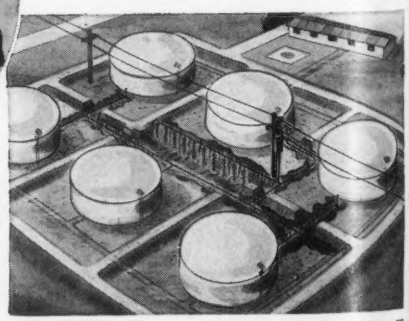
Here are shown only a few of the ways in which cathodic protection is helping to reduce corrosion damage of critical materials — damage estimated by one authority to be in the neighborhood of $6 *billion* annually.

WRITE FOR CATALOG SECTION S-6510





INDUSTRIAL PLANTS — External corrosion of buried or submerged metal structures can be completely eliminated by the use of "National" Ground Anodes.



TANK FARMS — The cost of a complete "National" Anode installation for the protection of a tank farm, including the cost of rectifiers, is frequently paid for within a very few months with savings from reduced structure maintenance.

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Vol. 8

Corrosion Abstracts

CORROSION CONTROL — PROTECTS INDUSTRY — NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Index to CORROSION ABSTRACTS

Vol. 8 July, 1952 No. 7

	Page
1. GENERAL	
1.1 Miscellaneous	209
1.2 Importance	210
1.5 Directories of Materials	210
1.7 Organized Studies	212
2. TESTING	
2.2 On Location Tests	212
2.3 Laboratory Methods and Tests	214
2.4 Instrumentation	218
3. CHARACTERISTIC CORROSION PHENOMENA	
3.3 Biological Effects	218
3.5 Physical and Mechanical Effects	218
3.6 Electrochemical Effects	220
3.7 Metallurgical Effects	220
4. CORROSIVE ENVIRONMENTS	
4.3 Chemicals, Inorganic	220
4.6 Water and Steam	220
5. PREVENTIVE MEASURES	
5.2 Cathodic Protection	220
5.3 Metallic Coatings	221
5.4 Non-Metallic Coatings and Paints	221
5.8 Inhibitors and Passivators	222
5.9 Surface Treatment	223
5.10 Other	224
6. MATERIALS OF CONSTRUCTION	
6.1 General	224
6.2 Ferrous Metals and Alloys	224
6.3 Non-Ferrous Metals and Alloys—Heavy	225
6.4 Non-Ferrous Metals and Alloys—Light	226
6.5 Metals Multiple or Combined	226
6.6 Non-Metallic Materials	226
6.7 Duplex Materials	228
7. EQUIPMENT	
7.1 Engines, Bearings and Turbines	228
7.3 Pumps, Compressors, Propellers, Impellers	229
7.4 Heat Exchangers	230
7.5 Containers	230
7.7 Electrical, Telephone and Radio	230
8. INDUSTRIES	
8.3 Group 3	231
8.4 Group 4	232
8.5 Group 5	233
8.8 Group 8	236
8.9 Group 9	236

1. GENERAL

1.1 Miscellaneous

1.1

Corrosion of Metals: Glossary. German Draft Specification DIN 50900, February 1950. G. SCHIKORR. *Z. Metallkunde*, **41**, No. 3, 91-93 (1950); *Werkstoffe u. Korrosion*, **1**, No. 3, 112-115 (1950).

A glossary of German terms relating to all types of corrosion: chemical, electrochemical, cavitation, erosion, stress-corrosion, and oxidation. Methods of testing and types of testpieces and corrosive media are also dealt with. This glossary is similar to the Glossary of Terms Used in Corrosion (*Trans. Electrochem. Soc.*, **90**, 585 (1946); *Met. Abs.*, **15**, 40 (1947-1948).—MA.

1.1

Critical Comparison Between the Italian, French and American Classification of Metallurgy. MASSIMO SCORTECCI. *Metallurgia Italiana*, **43**, 110-120 (1951).

There are, at present, three main systems for the classification of metallurgical literature. The characteristics of the layout are examined in detail, and from the reciprocal comparison arises the opportunity to make use of an index of symbols expressing a combination among the different points of view all reflecting the same subject.

To this aim the American ASM and the Italian AIM Associations have taken steps making use, however, of different principles and means, for its realization. In any case, it is believed that the ASM classification, more nimble than the Italian, possesses greater principles of practicity whilst its practical application

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CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

with the system of the edge punched cards introduces a marked limitation to its use and, therefore, it is less useful and less general than the Italian classification.—MI.

1.2 Importance

1.2.1

What Management Expects From the Corrosion Engineer. JOHN J. JACOB, JR. Presented, fall meeting Pittsburgh Section, Nat'l Assoc. Corrosion Engrs., October 19, 1950. *Corrosion*, **7**, No. 3, 84-87 (1951) March.

Modern technology has created a need for the corrosion engineer, and management should appreciate what the corrosion engineer can do to limit losses from corrosion. The corrosion engineer must have the cooperation and confidence of management, but should not be expected to function at the policy level. The corrosion engineer should be able to achieve his ends by persuasion and by maintaining good relations with his co-workers. Many companies' managements fail to recognize their corrosion problems and fail to provide adequate engineering personnel to cope with it. Suggested savings can be realized by the engineer recommending materials and procedures combating corrosion and consulting with operating personnel regarding feasibility of proposals. The engineer in charge of corrosion mitigation should be able to write reports understandable by management.

Editor's Note: This paper was approved for publication in the technical section of Corrosion because it will help promote understanding between engineers and management and in the end may intensify efforts in controlling corrosion.

1.2.2, 5.4.5

At What Price Does an Expensive Paint Become a Good Bargain? G. DECHAUX. *Official Digest Federation Paint and Varnish Production Clubs*, No. 311, 1066-1075 (1950); *Peintures, Pigments, Vernis*, **27**, No. 4, 212-218 (1951).

Details are given of a method by which the economics of the maintenance of steel structures by painting may be represented and assessed graphically. The title derives from the concept that although a paint may cost more originally, it will last longer than one of lower initial cost. Examples of the method are given.—RPI.

1.2.5, 6.4.4, 4.4.5

Aluminium Explosion Hazards—Violent Reactions With Chlorinated Hydrocarbons. *Chem. Age* (London), 63, No. 1620, 155-157 (1950) July 29.

The Underwriters' Laboratories, Inc., Chicago, has investigated the reports that fires or explosions were caused by the reaction of aluminum with carbon tetrachloride or methyl chloride. Tests were conducted under various conditions using magnesium powder or aluminum exposed in contact with carbon tetrachloride, methyl chloride, trichloroethylene, dichlorofluoromethane, or carbon tetrachloride-chloroform mixtures. Results indicate that aluminum powder in contact with methyl chloride, carbon tetrachloride, or a carbon tetrachloride-chloroform mixture is capable of explosion; methyl chloride in contact with aluminum may form spontaneously combustible aluminum methyl. A bomb containing aluminum powder and carbon tetrachloride exploded violently after heating to 152° C (305.6° F) in 53 minutes. At ordinary temperatures (29.4° C or 85° F) and in the presence of a small amount of aluminum chloride as a catalyst, aluminum powder and methyl chloride reacted, first with the gradual formation of gaseous pressure in a closed bomb, and after 41 days with more rapid pressure rise to more than 1800 psi. The residue of the reaction readily ignited spontaneously on contact with air or water, and burned especially vigorously on water. Aluminum or magnesium with carbon tetrachloride, chloroform, or trichloroethylene did not explode readily when under impact tests of hammer blows. Fifteen tests were carried out at ordinary or moderately elevated temperatures, and results are described and tabulated.—ALL.

1.5 Directories of Materials

1.5, 8.8.1, 6.2.1

Review of Ferrous Metals Used in the Chemical Industry. N. P. INGLIS. Paper before Soc. Chem. Ind., Birmingham, Apr. 18-20, 1950. Materials of Construction in the Chemical Industry, 1950, 91-97.

Brief review of some of the more important ferrous metals in use in the chemical industry today and some of the outstanding requirements and the trends of likely developments in the field. The review is divided into the sub-divisions of mild steel, steels of low alloy content, highly alloyed steel and cast iron. Where pressure vessels are made in alloy steel

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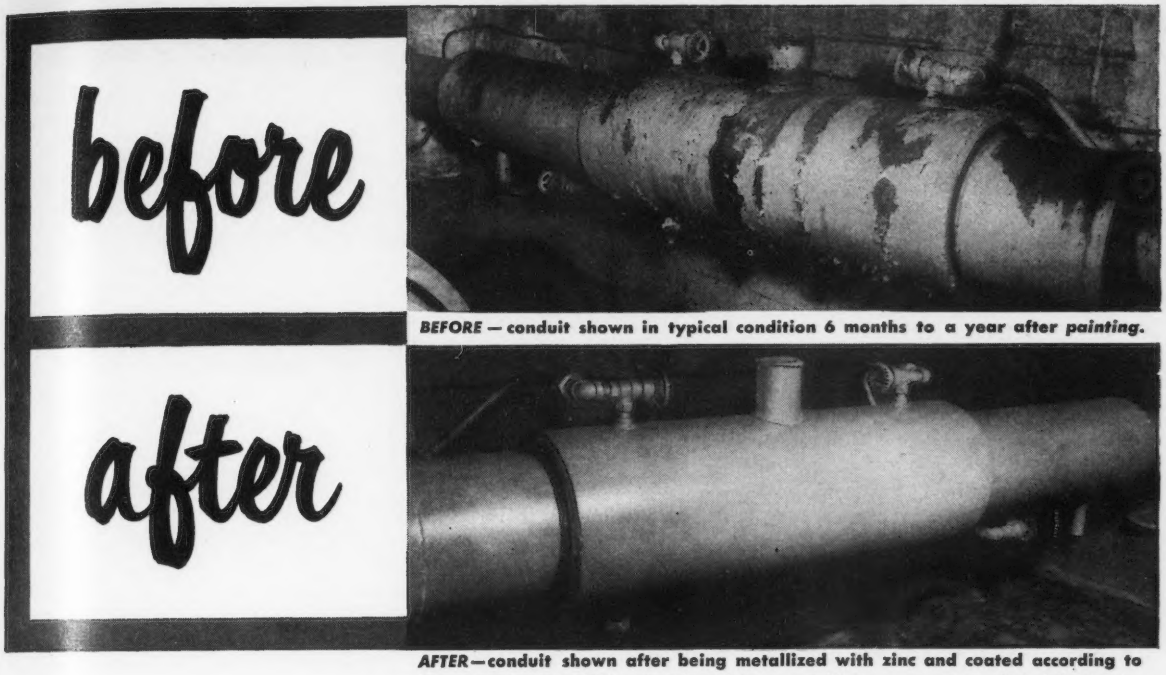

BEFORE — conduit shown in typical condition 6 months to a year after *painting*.

***AFTER*—conduit shown after being metallized with zinc and coated according to Metco System No. 103 by Metalweld, Inc., metallizing contractors, Philadelphia, Pa.**

old paint job lasted 6 months —metallizing treatment lasts indefinitely

The Philadelphia Electric Co. has had considerable maintenance on these underground conduits which are practically immersed in water for a large part of each year. The average paint job would last from 6 months to one year before it flaked off. In the meantime rusting had been going on under the paint coating during this period.

The first of these conduits was metallized with zinc over two years ago – the zinc then being covered with a vinyl after-coat in accordance with Metco System No. 103. Careful periodic inspections have revealed *no apparent changes* in the coating over this period. Even when the vinyl after-coat fails, which may conceivably occur after 5 years or so—the zinc coating is still there providing complete protection against corrosion and it will only be necessary to replace the vinyl after this extended time. Even this will be very inexpensive compared to the replacement of the previous paint jobs, since there will be no rust or paint flake requiring removal by wire-brushing or sandblasting, a comparatively expensive procedure.

Metallize 'Em—And You Can Almost Forget 'Em. The following organizations are set up to provide positive corrosion protection at lower annual cost in accordance with Metco* System specifications. For further information, or copy of descriptive bulletin, contact the one nearest you.

** Reg. U. S. Pat. Off.—Property of Metallizing Engineering Co., Inc.*

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are a series of 18 basic engineering specifications developed over 19 years of experience with pure zinc and aluminum coatings on many different types of structures and equipment. The Metco Systems provide the answer to standardization of surface preparation, metal coating thicknesses and organic after-coatings for various service conditions and appearance requirements.

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simply because the high strength, as compared with mild steel, gives a more economical construction, the choice of possible steel compositions is fairly wide and has embraced nickel-chromium-molybdenum steel, chromium-molybdenum steel and others. Many of the previously used high tensile bolt materials (nickel-chromium-molybdenum seeel, 3 nickel steel, etc.) suffer very marked reduction in notched impact value after only a few hours in 400°-500° C range. 18-8 titanium steel was developed to overcome the problem of weld decay of welded 18-8 steel. The corrosion resistant property of 18-8 steel is discussed with the effect of additions to the steel. The moves taken to produce a steel with desirable corrosion resistant characteristics associated with molybdenum additions but with a much diminished tendency towards the formation of sigma phase on heating minimum 10 nickel and reduce to 2.5-3.0 molybdenum content. Stainless clad steels are discussed. In discussing cast iron, it is mentioned that austenitic cast irons, usually containing 14 nickel, 7 copper and 2 chromium, have a fair resistance to corrosion by certain concentrations of sulfuric acid and have been used as impellers and valves in service where ordinary cast iron is not good enough. Illustrations are included. 13 references.—INCO.

1.5, 6.5

Corrosion-Resistance Materials. L. W. JOHNSON AND E. J. BRADBURY. Paper presented to the Insitute of Marine Engineers (England), February 13, 1951. *The Chartered Marine Engineer* (England), **2,** No. 1, 1 (1951) Jan.; Abstract, *Inst. Marine Eng. Trans.*, **63,** No. 3, 36 (1951) Mar.

The authors discuss the various forms of corrosion to which metallic materials are subjected, and give a brief survey of the main corrosives which are encountered as well as the effect of other influences such as chemical composition, surface condition and physical properties. They also deal with the general corrosive behavior at both room and elevated temperatures of both non-ferrous and ferrous materials and brief details are given of the principal physical properties of these metals and alloys. Opportunity is also taken in this latter section of the paper of drawing attention to special properties of these materials with a view to aiding the marine engineer in selecting the most appropriate material for some of the particular service problems he encounters.—ALL.

1.5, 6.1

"Chemical Engineering." 14th Chemical Engineering Materials of Construction Report (1) Materials of Construction. (2) Directory of Materials. *Chem. Eng.*, **57,** No. 11, 107-142+ (1950) Nov.

1) Gives concise accounts of the behavior of various constructional materials in contact with selected chemicals, with mention of particular applications in present-day practice. Warning is given, however, that this report is intended only to narrow the field of choice; further details or actual tests may be required before making a final selection. Materials include aluminum, lead, nickel, tantalum, Chlorimets, Durimet 20, Duriron, Durichlor, iron, Worthite, carbon and stainless steels, carbon, organic coatings, glass and rubber linings, silicons, stoneware, etc. Chemicals dealt with are: acetic acid, ammonia, sodium hydroxide, hydrochloric acid, fatty acids, chlorine, hydrofluoric acid, nitric acid, phosphoric acid, sodium chloride, sulfur, sulfur dioxide and sulfuric acid. 2) lists corrosion-resistant materials (metals and alloys, carbon, graphite, cement, ceramics, plastics, refractories, rubber) under the headings: material, manufacturer, description (gives alloy compositions), and most important applications; degree of corrosion resistance is not indicated.—BNF.

1.7 Organized Studies of Corrosion

1.7.1, 1.8, 8.9.4

Technical Practices Committee 15—Corrosion Control in the Transportation Industry. M. A. WILLIAMSON. Pullman-Standard Car Mfg. Co., Hammond, Ind. *Corrosion*, **7,** No. 4, 113-114 (1951) April.

Technical Practices Committee 15 of the National Association of Corrosion Engineers was organized early in 1949 ultimately to study corrosion problems in all fields of transportation, excluding pipe lines and marine. Initial organization was directed toward corrosion problems in the railroads only, with objectives including stimulation of research, exchange of knowledge, promotion of standardization and others. Members of the committee are named.

1.7.1

The Literature on Corrosion. IVY M. PARKER, Plantation Pipe Line Co., Bremen, Ga. Editor, Corrosion, official publication Natl. Assoc. Corrosion Engrs., Houston, Texas. Presented to The Metals Section of the Special Libraries Association at World Metallurgical Congress, Detroit, Mich., October 15-19, 1951. *Corrosion*, **7,** No. 12, 450-454 (1951) Dec.

The increasing economic importance of corrosion has resulted in more attention being devoted to its causes and to means whereby it may be mitigated. Several technical societies at home and abroad have corrosion as a specific field of interest, and the National Association of Corrosion Engineers devotes its attention to it exclusively.

Corrosion literature is being published in magazines ranging from the smallest trade magazine to the most learned technical journal. A survey of 3,300 abstracts of corrosion technical literature published in 1946-47 showed 542 source publications. The American Coordinating Committee on Corrosion concluded the literature on corrosion could not be sectionized because it cut across many fields.

NACE, not wishing to duplicate work already done, secured permission of established abstracting agencies to collect, classify and publish abstracts. The need for a filing system index to coordinate corrosion literature in a manner covering any field of interest and with provisions for expansion became evident with the start of the abstract program.

The NACE Abstract Committee developed a system and keyed to it a punch card to make semi-mechanical sorting possible. Random number codes are used in the system, among others, and the card finally developed includes provision for coding topics, authors, publications, and year of publication, besides leaving a substantial number of unassigned holes for use in supplementary indexing.

1.7.1, 1.8, 5.8.1

Objectives and Progress of Technical Practices Committee 9—Corrosion Inhibitors. A. WACHTER, Chairman TP-9, Shell Development Co., Emeryville 8, Cal. *Corrosion*, **7,** No. 5, 145 (1951) May.

Technical Practices Committee 9 of the National Association of Corrosion Engineers was organized to improve the science and technology of corrosion inhibitors. Primary aim of the committee is to collect and make available information on corrosion inhibitors, promote their proper use and promulgate recommended practices. The committee proposes to collect, digest and issue material on inhibitors as reports of the committee. Members of the committee are listed.

2. TESTING

2.2 On Location Tests

2.2.2, 4.5.4, 6.2.3

Study of Cutback Rust Preventives in Storage Tests. D. BOOTZIN. U. S. Arsenal, Rock Island, Ill. Report 49-1640; Project TB5-6101, Report 11 December 1949. 29 l., plates, tables, diagr.

A long-term storage test program showed that commercial cutback-type rust preventives provide adequate protection for indoor and shed storage but those preventives designed for outdoor protection are not satisfactory. The production of a reliable standard reference material is difficult because of the variability, especially in thixotropic behavior, of the protective films during storage. Important factors influencing the durability of these cutbacks include thickness and uniformity of the film, season of the year and prevailing weather when panels are put in test, amount of rainfall and sunlight, and degree of shelter.

AXS 1759 Grade 2 and 52 C 18 Grade 3 rust preventives, both soft films designed for indoor storage, lasted less than 4 days outdoors, 1-3 months in shed storage, and longer than 2 years in indoor storage.

AXS 1759 Grade 1, 52 C 18 Grade 2, and AN-C-124 Type 1 rust preventives, all soft, medium-thick films designed primarily for sheltered storage but having limited outdoor use, provided protection for 2-3 months outdoors, 1-3 years in shed storage, and longer than 3 years indoors.

AXS 673 dry film rust preventives intended for outdoor storage performed adequately for 2-6 months outdoors, longer than 3 years in shed storage, and at least equally long indoors. For these cutbacks, spring was more conducive to film breakdown than fall. The coating of one of these compounds deteriorated to a hard, dry, difficult-to-remove film, resulting from the action of the sun's ultraviolet light.

The rust preventives were applied to clean, polished X1010 low-carbon steel panels, 2 by 3 by 0.125 in., by dipping at 75° ± 2° F. The dried panels were exposed on racks outdoors at 45° facing south, in a roofed shed having louvered sides, or in an unheated warehouse attic. Weathering factors were studied by adding and withdrawing test panels at regular intervals throughout the year.

2.2.5, 5.3.1, 5.4.1

Report of Protective Coatings Investigation Underwater Exposure Tests, 1941-1949. Summary and Conclusions. H. W. MUNDT, L. J. THOMPSON AND S. J. STACY.

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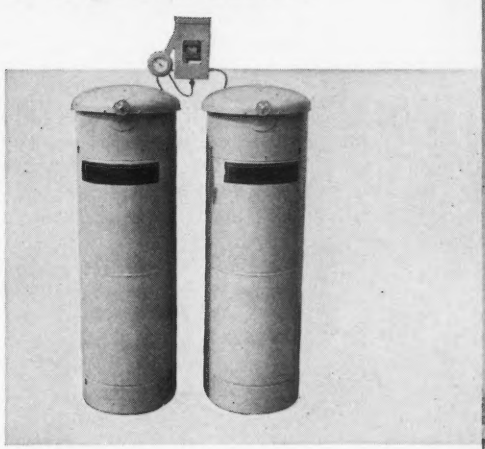

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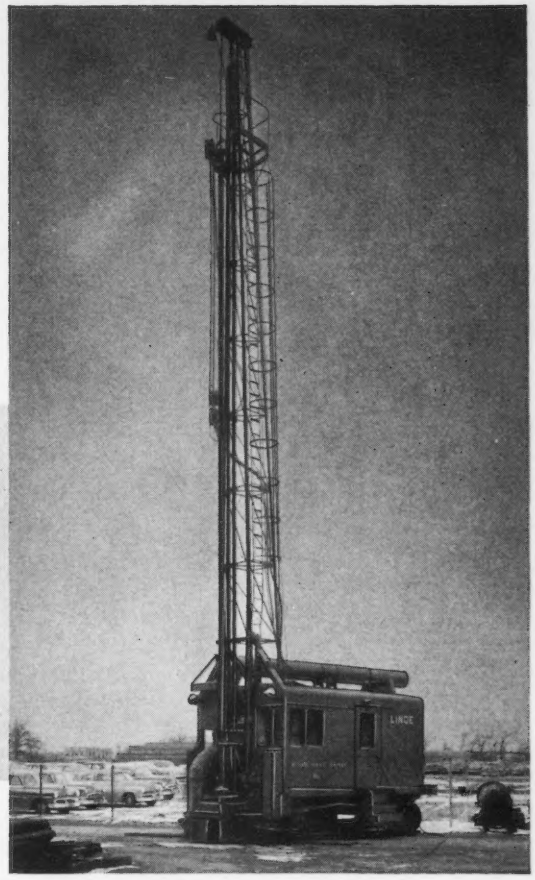

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This report, dated March 1950, was based on investigations conducted by the Department of Operation and Maintenance, United States Panama Canal, Balboa Heights, Canal Zone. *Corrosion*, **7**, No. 2, 50 (1951) Feb.

Conclusions reported are: a) zinc-metallized systems show outstanding performance; b) metallizing provides secondary protection; c) metallizing not justifiable economically if service period length is 4-5 years or less; d) for priming zinc-metallized surfaces zinc tetroxychromate pigment in Bakelite resin and other components is recommended; e) for sandblasted surfaces 80 percent zinc dust, 20 percent zinc oxide in aforementioned vehicle is best; f) critical value for film thickness (Series A and B Systems) appears to be about 4-5 mils minimum for 5-year life except, 1) zinc metallized surfaces not at end of service life, 2) sandblasted and millscale-intact specimens coated with certain systems. Short term and/or accelerated tests may be unreliable as long-term performance indicators.

2.3 Laboratory Methods and Tests

2.3.2, 2.3.7, 6.4.2

Report of Test of Aluminum Alloy Castings Submitted By Acme Aluminum Alloys, Inc. L. THOMPSON AND W. H. ASCHE, U. S. Naval Engineering Experiment Station, Annapolis, Md. (Report C-2643-C) February 1949. 15 l., plate, tables, diagrs.

Two aluminum alloys, one containing 11.22 percent magnesium and 0.23 percent beryllium, the other containing 10.71 percent magnesium, were both aged 4 hours and 24 hours at 212° F, and subjected to stress-corrosion tests along with an unaged alloy containing 4.41 percent copper and less than 0.05 percent magnesium. On the basis of these tests, the 4-hour aged alloy containing magnesium and beryllium, and the alloy containing copper were more susceptible to stress corrosion than the 4-hour aged alloy containing 10.71 percent magnesium. Both of the alloys after 4-hour aging showed higher Charpy impact values and greater stress-corrosion resistance than after 24-hour aging. It was recommended that the aluminum alloy containing magnesium and beryllium not be used under severe stress-corrosion conditions.

Potential values determined from measurements made on stressed and unstressed specimens of the aluminum alloy containing magnesium and beryllium against a saturated calomel half-cell for 1-52 hours indicated that the aluminum alloy was less noble than the reference cell, with a gradual decrease in potential with time. The decrease was probably caused by a protective film forming on the surface of the material. The measurements indicated no appreciable potential difference between stressed and unstressed specimens immersed in Severn River water.

For the stress-corrosion tests, two specimens of each alloy were mounted in tandem on an apparatus devised for this test. The beam ratio of the apparatus was 9.1. The gage length was subjected to corrosion while under stress by spraying the specimens with Severn River water 3 minutes followed by a 17-minute drying period. The specimens were tested at 60, 70, 80, and 90 percent of the tensile yield strength until failure. The temperature of the test was 95° ± 3° F. After a specimen under stress and corrosion failed, the duplicate stressed specimen and the corroded unstressed specimen were removed from the apparatus and the tensile strength of each was determined, these values in conjunction with the strength of the material before exposure were used to evaluate the stress-corrosion susceptibility of the material.

2.3.4, 6.2.4, 4.6.1

Corrosion-Resisting Steels and Their Behavior Toward Natural Waters. E. HERZOG. *Chimie et Industrie*, **41**, (1939), Special Issue No. 4, 453-459.

Corrosion tests in sea water and fresh water on plain carbon steel sheet containing 0.08 percent carbon, 0.4 manganese, and 0.09 copper in as-pickled state and on steel sheet containing 2.3 percent chromium, 1.2 aluminum, and 0.1% copper, passivated by chromates. Eleven-month alternating test conducted at laboratory on above steels, as-painted and as-descaled. Translation available Henry Brutcher, Box 157, Altadena, Calif.

2.3.4, 6.4.2

Solubility and Volatility of Aluminum in Aqueous Solutions or in a Stream of Water Vapor. (In German.) R. STROHECKER AND FR. MATT. FRESENIUS. *Z. Anal. Chem.*, **131**, No. 5, 334-341 (1950).

Above was experimentally studied by dissolving aluminum and several of its compounds in tap water, distilled water, and dilute solutions of sodium chloride, acetic, tartaric, citric and oxalic acids. The effect of boiling in the solvent in

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The Use of Ammonia in Control of Vapor Zone Corrosion of Storage Tanks by F. T. Gardner, A. T. Clothier and F. Coryell.

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Salt Spray Testing Bibliography by Lorraine Voight.

The Cost of Corrosion to the United States by H. H. Uhlig.

Why Metals Corrode by H. H. Uhlig.

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open and in closed vessels was also investigated. Data are tabulated. 10 references.—BLR.

2.3.4, 2.3.5, 5.4.1

Pipe Coating Evaluation By Salt Crock Tests. S. K. GALLEY. Paper, Pacific Coast Gas Assoc., Technical Service Group Conf., Los Angeles, Apr. 28-29, 1949. *Gas*, **25**, No. 12, 86-89 (1949) Dec.

The "salt crock test" for the preliminary evaluation of pipe coatings is made by immersing coated pipe nipples in a standard saline solution, while continuously maintaining a six-volt potential between the nipple and solution. Failure of the coating is indicated by a decrease in the electrical resistance between the test nipple and the solution, usually followed by a visible break in the coating with a resulting rapid corrosion of the underlying metal. Coatings which show no decrease in resistance are tentatively considered to have passed the test at the end of 60 days and definitely so after six months. Procedures for applying various type coatings to the test nipple are described briefly.

2.3.7, 2.5

Film Thickness Measurements. E. J. DUNN. *A.S.T.M. Bull.*, **1951**, No. 172, 35-39, Feb.

A review of the work of an ASTM Committee appointed to draw up standards for the measurement of organic coating thicknesses. The following instruments are briefly described. The Magne gauge; the General Electric gauge; the Lipson gauge; the Filmeter; the R. W. Carson micrometer; and the Jack and Heintz electronic micrometer. Graphs compare the results obtained from measurements made on test specimens in 7 laboratories equipped with various instruments. Micrometer measurements were the most consistent and it is recommended that they be used to calibrate magnetic or electronic instruments.—ZDA.

2.3.7, 4.6.11, 3.5.3

The Jet-impingement Apparatus for the Assessment of Corrosion By Moving Sea-Water. R. MAY AND R. W. DE VERE STACPOOLE. *J. Inst. Metals* (London) **1950**, 331-344, June.

A jet-impingement apparatus for investigating the corrosive action of rapidly moving aerated sea-water upon condenser tube and sea-water pipes is described. Apparatus design details are given. Methods for removing fine air bubbles before re-circulation and for apparatus cooling to maintain a water temperature of 20° C or less are explained.

2.3.9, 6.6.4

New Method For Evaluating Failure of Bituminous Materials Due to Weathering. J. B. HUNTER, F. C. GZEMSKI, AND L. LASKARIS. Symposium on Accelerated Durability Testing of Bituminous Materials, A.S.T.M. Spec. Tech. Pub., 1949, No. 94, 144-150, discussion, 151-152.

The common spark method in conjunction with a photographic technique is used. The method is simple, offers a permanent record of the failure pattern and shows rate of failure data.—RPI.

2.3.9, 5.9.2, 5.9.3

Improved Radioactive-Tracer Carrier for Metal-Cleaning Studies. J. C. HARRIS, R. E. KAMP, AND W. H. YANKO. *A.S.T.M. Bull.*, **170**, 82-83 (1950).

In a previous paper (*ibid.*, **158**, 49 (1949); *Met. Abs.*, **17**, 536 (1949-50), the authors described the measurement of the amount of soil remaining on metal specimens after various cleaning treatments, by incorporating in the soil a small quantity of NN-di-n-butyl steramide containing a radio-active carbon (C^{14}) atom, and counting the radioactive emissions before and after cleaning. A disadvantage was that the tracer compound used was chemisorbed to some extent and not removed completely by the most efficient cleaning methods. The present paper describes results using n-undecane as a tracer. Comparison with results using the amide confirmed that the latter was definitely chemisorbed while undecane was adsorbed to a much lesser extent. It has one disadvantage in being appreciably volatile. A preferable tracer would be a hydrocarbon with a chain length approaching that of the lubricating oil used as the soiling medium (20-30 carbon atoms), but this would be difficult to prepare containing the C^{14} atom.—MA.

2.3.9, 5.3.4, 5.4.1

Examination of Plated and Protective Coatings by Electrographic Analysis. N. GALITZINE AND S. E. Q. ASHLEY. A.S.T.M. Symposium on Rapid Methods for Identification of Metals (1949), 1950, 6-68.

The application of electrographic analysis to the detection of holes and discontinuities in coatings on metal is described and discussed.—MA.

2.3.9

Radioactive Tracers Used in Corrosion Studies. CONRAD G. BACON, General Electric Co., Schenectady, N. Y. *Gen. Elec. Rev.*, **52**, No. 5, 7-9 (1949) May.

Radioactive tracers now available from the U. S. Atomic Energy Commission at Oak Ridge, Tenn., are formed from isotopes of common metals and of some nonmetal elements, which have been made radioactive in an atomic chain-reacting pile. These tracers are of value in studying chemical combinations and processes taking place in corrosion:

The corrosion of iron was studied by plating a polished surface with a thin layer of radioactive iron 55 and 59. A reference photograph of the original metal plate as it came from the plating process was obtained and the sample was then exposed to attack by corrosion. After exposure for a given length of time, the radioactive surface was blown dry with compressed air and placed in close contact with the emulsion side of a photographic plate for 3 days. A plate-and-developer combination was used to obtain the maximum contrast. The developed plate clearly showed the details of the corrosion process.

Spots of iron oxide initiating corrosion were indicated in the autoradiograph by a decrease in density of the developed plate area at those points; the iron diluted with oxygen does not have the same concentration as the original parent-metal surface of the surrounding area. A second factor in the process is that the layer of iron oxide begins to absorb the radiation arising from the underlying iron. Finally, when the radioactive material is completely removed from the area in question (removed by some solution process or by the formation of soluble salts and the consequent carrying-away of the active material) a "dead" spot in the radioactivity remains.

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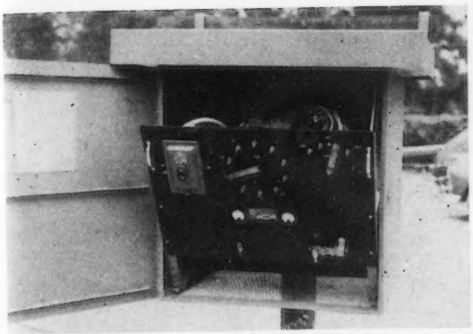

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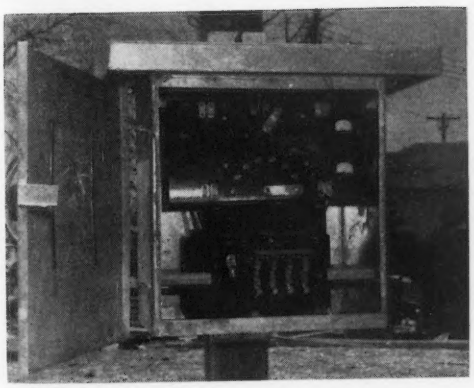

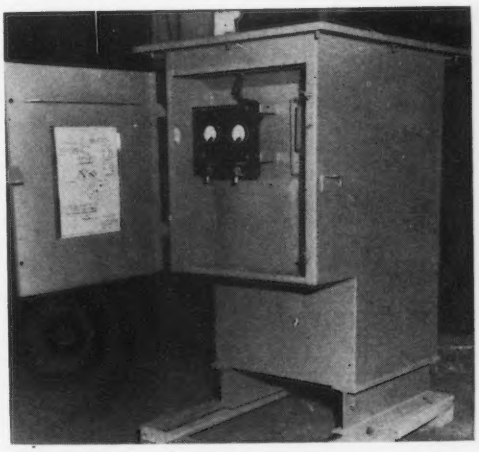

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tivity at the surface of the radioactive layer by even slight pitting of the iron surface.

A photograph of the corroded metal plate showed the different reflection characteristics of the constituents of the corrosive action, but detection of the precise location of these constituents was impossible. In the autoradiograph of the corroded plate, however, the lights and darks were definitely outlined and the location of the radioactive iron was accurately recorded.

2.4 Instrumentation

2.4.3

Automatic Inspection of Pipe. J. E. CLARKE, R. A. PETERSON, AND T. J. DUNSHEATH. *Welding Engr.*, **36**, 38-42 (1951) Feb.

Illustrates new magnetic-particle equipment which inspects seam-welded pipe just after it leaves the welding wheels.—BLR.

3. CHARACTERISTIC CORROSION PHENOMENA

3.3 Biological Effects

3.3.4, 3.4.7, 8.4.3

Bacterial Casing Corrosion in the Ventura Field. KEITH DOIG AND A. WACHTER. Paper, 7th Ann. Conf., Natl. Assoc. Corrosion Engrs., New York, N. Y., March 13-16, 1951. *Corrosion*, **7**, No. 7, 212-224 (1951) July.

The corrosion of well casings in the Ventura Avenue field has become an increasingly important problem during recent years. In the seven-year period since the first leak occurred a total of 40 well casings have failed because of corrosion. A statistical prediction of the future failures now indicates that about 75 percent of the 250 wells drilled between 1938 and 1950 may be expected to fail unless some reduction in failure rate is effected. The inaccessible location of the leaks made it necessary to conduct most of the investigation on a basis of theory, statistics, surface measurements and remote controlled subsurface measurements. In some cases it was necessary to develop new tools in order to make the subsurface measurements. Among the possible causes of corrosion which were considered and in general refuted during this phase of the study were particular corrosive strata, defective steel, electric currents in casing or flow lines and interzonal migration of salt water. Concurrent attempts were made to develop means of preventing the failures. The more important methods considered were cathodic protection, insulating flanges on wellhead connections, protective coatings, extra casing strings and full-string cementing. Neither the study of possible causes nor the study of preventives yielded positive results. However, there were some indications that salt water could be migrating behind the well casings. These indications caused the adoption and use on 19 wells of the full-string cementing practice.

The turning point of the investigation occurred when the corroded casing was recovered from one well. This made it possible to minutely analyze the material relevant to the problem including the corroded steel, the corrosion products, the formation adjacent to the leak and the residual drilling fluid cake. The results of the analysis plus further statistical study has led to the conclusion that bacterial activity is responsible for the corrosion which has been experienced. Research has also developed methods for inhibiting or destroying the bacteria. Alkaline environments were known to be inimical to bacterial activity and laboratory and field testing showed that the use of high pH drilling fluids would create such an environment adjacent to the well casings. The testing also showed that in addition to probably preventing corrosion, the high pH drilling fluids are thoroughly satisfactory from an operational viewpoint. Therefore, this type of fluid is now used for drilling to the casing point in all Shell wells in the Ventura Avenue field. The foregoing partial solution to the problem is applicable only to wells yet to be drilled.

3.5 Physical and Mechanical Effects

3.5.8, 7.2

Corrosion Fatigue Cracking in Steam Pipe Systems at Power Stations. *Beama J.*, **56**, 381-385 (1949).

Corrosion-fatigue failure in steam pipe systems occurs in the form of cracks in the metal, caused by either mechanical or thermal cyclic stress. Where the stress is highest, the initial cracks may propagate along the slip planes of the grains in the metal, resulting in transgranular cracks without apparent deformation. The resistance of the metal to fatigue cracking is initially weakened by surface defects, scratches, tool marks, and sharp changes of section, which induce greater-than-average concentration of stress on the metal.

Mechanical stress results from bending loads from vibration of the pipe, or from restriction of the ordinary expansion of metal in contact with varying temperatures. Some of the failures attributable to these causes occur where condensate lies in contact with the metal.

Thermal stress is the more important cause of corrosion-fatigue failure and is created by repeated sudden cooling of an area of the metal either by condensate or by the desuperheating water intentionally introduced into the pipe system. Any wetting of a metal reduces the endurance of the metal; if the liquid contains dissolved gases or solids, or produces noticeably active chemical attack on the metal, the endurance of the metal may be seriously impaired. In a superheated steam system, the metal surface is usually at a much higher temperature than the steam. When water contacts the metal surface, a rapid reduction in temperature of the metal may occur locally, owing to the high rate of heat transfer and the large amount of heat that must be extracted from the metal to supply the latent heat of vaporization. This causes high local contraction with a resultant area of high tension. Since the endurance of the metal is already lowered by the presence of the water, the metal may crack. Most of the trouble experienced in steam pipe systems is due to the repetition of such a cycle.

Water in a spheroidal state that does not actually wet the surface of the metal is potentially dangerous. In this form the water may traverse the pipe system for long distances without effectively touching the metal surface. The spheroid may

at any time, however, be rapidly projected against the metal surface by a change in the direction of the flow, or be broken by coming into contact with a sharp edge of a branch or drain. The water then wets the metal and rapidly evaporates, quenching the metal. This type of wetting is facilitated by a surface to which deposits are adhering, a rough surface itself, or the pre-existence of fine cracks in the surface.

Steam receivers, auxiliary steam lines, and boiler steam mains are among the parts of a steam plant most subject to high fluctuating stresses and the corrosive action of water.

3.5.9, 4.7, 6.2.5, 1.7.1

TP-7 Plans Publication of Bulletin On Corrosion At Elevated Temperatures. M. A. SCHEIL. Chairman, TP-7 Materials for Use at High Temperatures; Director of Metallurgical Research, A. O. Smith Corp., Milwaukee, Wis. *Corrosion*, **7**, No. 6, 179 (1951) June.

Technical Practices Committee 7 of the National Association of Corrosion Engineers has completed a literature review of recent papers dealing with corrosion at elevated temperatures to be added to the compiled data on materials for use at temperatures above 400 degrees. The committee has discussed possible papers on corrosion by molten metals and effect of alloy substitution and composition restrictions on high temperature corrosion characteristics of stainless steels. An investigation is under way into the possibilities of a field exposure test for alloys in a special application where more information is important on the effects of carburization, especially on pitting characteristics.

3.4.6, 6.3.20, 6.3.6

Action of Hot Ionized Gases Upon Zirconium and Copper. ANDREW DRAVNIEKS. *J. Phys. & Colloid Chem.*, **55**, 540-549 (1951) Apr.

By measuring changes in electrical resistance the relative reaction rates of zirconium at 986°C with low-pressure ionized and nonionized oxygen, air, water vapor, carbon dioxide, carbon monoxide, nitrogen containing 0.5 percent oxygen, ethane and technical helium were studied. In some cases an acceleration and in others a retardation of the reaction upon ionizing the gas was observed. The retardation may be explained by a cleanup effect on the surface of the metal or reaction film by the nonreacting components of the gas phase. The oxidation in water vapor was abnormally fast as compared with the oxidation in oxides of carbon or in nitrogen with 0.5 percent oxygen. The oxidation of copper in both forms of gases was studied at 750°C. The ionization of carbon dioxide caused a slow oxidation of copper, which proceeded according to the parabolic law. Copper did not undergo oxidation in ionized or nonionized carbon-monoxide. A method of recording continuously the progress of the oxidation of metal strips is described. 31 references.—NSA.

3.6.5, 6.3.19

Potential-pH Diagram of Zinc and Its Applications to the Study of Zinc Corrosion. PAUL DELAHAY, MARCEL POURBAIX, AND PIERRE VAN RYSSELBERGHE. *J. Electrochem. Soc.*, **98**, 101-105 (1951) Mar.

On the basis of methods and conventions previously described and using available thermodynamic and electrochemical data, the above diagram was

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TECHNICAL TOPICS

Magnetism in Austenitic Stainless Steel

NORMAN S. MOTT
Chief Chemist and Metallurgist

In the normal specification range for the 18-8 chromium-nickel stainless steels, especially when the carbon is low, ferrite and the resultant magnetism will often be found. It must not be construed, however, that this condition is detrimental to the properties of stainless steel; in fact, in many cases it is highly desirable.

The fully austenitic stainless steels, when heated in the carbide precipitation range (900-1600° F.) have their carbon precipitated as chromium carbide along the grain boundaries. This depletes the boundaries of chromium with the result that the alloy becomes susceptible to intergranular corrosion.

When alloys containing amounts of ferrite from 5-15% are heated in this temperature range, it is found that carbides tend to form predominantly in the ferrite areas. Since these areas are disconnected and well distributed, the condition does not promote intergranular corrosion.

Stainless steels with free ferrite up to 30% in amount retain good mechanical properties, although they show a slight decrease in ductility and toughness. Their strength and hardness are increased.

Estimation of the presence and approximate amount of ferrite may be accomplished by the use of a phase diagram based upon nickel and chromium equivalent values.* The nickel and chromium equivalent values are computed by the equations:

$$Ni^e = Ni\% + 0.5\,Mn\% + 30\,C\%$$
$$Cr^e = Cr\% + Mo\% + 1.5\,Si\% + 0.5\,Cb\%$$

The boundary line between fully austenitic alloys and those which contain ferrite is expressed by the equation:

$$Ni^e = \frac{(Cr^e - 16)^2}{12} + 12$$

When a higher percentage of nickel is specified in type 316 moly bearing alloys in order to make them completely austenitic in structure, they become susceptible to intergranular corrosion; and if they are to be heated in the carbide precipitation range, as would occur during welding, additions of columbium are required to counteract this susceptibility. Molybdenum additions to 18-8 stainless make the alloy magnetic due to the formation of ferrite, and existing data have shown that the presence of this ferrite does not interfere with the high corrosion resistance of the alloy. In this form, it enjoys a wide range of usage where excellent resistance to corrosive media and the effects of welding heat are required.

* A. L. Schaeffler, Metal Progress, November, 1949, p. 680-B

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constructed. Derived diagrams showing domains of corrosion, passivity, and passivation in the absence and presence of carbon dioxide, bicarbonates, and carbonates are also presented. 11 references. —BLR.

3.6 Electrochemical Effects

3.6.5, 3.4.8

Electrochemical Behavior of Iron in Solutions of Oxidizing Agents. I. Electrode Potentials of Iron in Solutions of Oxidizing Agents. II. Anodic Polarization of Iron in Solutions of Oxidizing Agents. (In Russian). L. Ya Gurvich and G. V. Akimov. *Izvestiya Akademii Nauk SSSR* (Bulletin of the Academy of Sciences of the USSR), Section of Chemical Sciences, **1950**, 565-572, Nov.-Dec.

I. The above potentials were determined in 0.0001-0.1 normal nitric acid solutions and in solutions of potassium nitrate, potassium dichromate, potassium permanganate and ammonium persulfate. Influence of ferric ions on electrode potentials of iron was also studied. Method of investigation is described and data are charted.

II. Anodic polymerization of iron in solutions of potassium permanganate, potassium dichromate and ammonium persulfate was studied. Results are tabulated and charted.—BLR.

3.6.9, 8.9.4

Investigation of Electrolytic Corrosion. *Elect. Engr. and Merchandiser*, **27**, No. 7, 211-212 (1950).

The main problem is the flow in underground structures of currents originating from electric railways or tramways causing corrosion where they leave these structures and pass into the soil. The usual remedy is to provide a metallic path to take the current from the structure discharge point directly to the rail without passing through the soil. —MA.

3.7 Metallurgical Effects

3.7.3, 3.3.3, 3.5.8

Investigation of Soft Soldered Joints. Robert M. Evans, A. F. Haskins, Webster Hodge and B. W. Gonser. Battelle Memorial Institute, Columbus. Final Report; U. S. Air Materiel Command Contract AF33 (038)-3296, November, 1950. 44 l., plates, tables, diagrs.

A study was made of the effects of temperature, aging, vibration, and fungus growth on the strength of soft-soldered brass-to-brass joints. The solders were of the type specified in Fed. Spec. QQ-S-571b. viz., 70-30, 50-50, and 20-80 tin-lead, and 95-5 tin-antimony, as well as two additional solders tested only for impact resistance, viz., 36-65 tin-lead and 97.5-2.5 lead-silver.

If properly constructed, a soft-soldered joint withstands a variety of temperature, loading, and climatic conditions. The 70-30 and 50-50 tin-lead solders showed the best overall performance under all test conditions; solder compositions other than those in the 50-50 tin-lead range do not seem required for any normal use; the convenient-use properties of the 50-50 tin-lead solders more than compensate for any small advantages of other formulations.

Lowering the temperature to 65°C raised the tensile strength of all soldered joints tested. Raising the temperature to 120°C lowered the tensile strengths.

Under constant load, 95-5 tin-antimony was slightly superior to 70-30 tin-lead, but was much weaker in fatigue strength at room temperature; the tension properties of the two solders were equal. This indicates the superiority of the tin-lead solder for vibratory loads at room temperatures; cold-aging slightly impaired its impact strength. The 20-80 tin-lead solder should not be used, especially at high temperatures.

Aging in the presence of tropical fungi at high humidity had no effect on either tensile or impact strength that would not occur during ordinary aging. In general, little fungus growth occurred on the specimens, probably because of the fungicidity of the copper-bearing substrate and because the specimens were not contaminated with residual soldering flux. Cycling between hot, cold, and moist tropical conditions gave the same results as did room temperature aging.

4. CORROSIVE ENVIRONMENTS

4.3 Chemicals, Inorganic

4.3.2, 6.1

Hydrochloric Acid versus Construction Materials. *Chem. Eng.*, **56**, No. 3, 251-2 + (1949) Mar.

The corrosivity of hydrochloric acid to various structural materials is discussed in the following articles: "Chemical Stoneware", F. E. Herstein, p. 251; "Glass-lined Steel", S. W. McCann, pp. 25-2; "Protective Coatings", pp. 252, 254, 256; "Chemical Porcelain", W. V. Lapp, pp. 256, 258.

4.3.3, 6.1

Caustic Soda Versus Construction Materials. *Chem. Eng.*, **57**, No. 1: 213-14, 216 (1950) Jan.

The effect of caustic soda on rubber linings, high-silicon iron, stainless steel, cements, chemical stoneware, aluminum, and tantalum is discussed by various authors.

4.3.6, 4.6.9, 8.4.3

Refinery Problems Occasioned By Salt in Crude Oils. G. Armistead, Jr. *Petroleo Interamericano*, **7**, No. 4, 44-46 (1949) Apr.

The difficulties occasioned in refinery processing by the presence of salt in crude are corrosion, plugging of exchangers and furnace coils and the contamination of residual products. Corrosion resulting from chloride hydrolysis and the measures required for protection against it are generally proportionate to the salt content. The allowable limits of salt are determined in the main by the concentration at which troublesome deposition will occur. In crude-distillation operations troublesome deposition is usually to be expected (salt content above 20 lb. per 100 bbl.) when salt enters the equipment in water solution. If the oil is entirely free from water no salt deposition is likely to occur with concentrations as high as 150 lb. per 1000 bbl. in tubes and other turbulent zones. In thermal cracking coils, concentration of 20 lb. per 1000 bbl. or over will give trouble in zones where crack per pass is in the neighborhood of 15 percent of the flowing stream. Salt content on the inorganic ash in residual products is important in the preparation of asphalts and road oils which have to meet solubility specifications. In the preparation of residual feed for catalytic cracking, a content of 20 lb. of salt per 1000 bbl. represents 300 lb. per day to a 15,000 b. per day cracking unit, which on the basis of 500 tons of catalyst is 0.03 percent added to the catalyst per day. The extent of such contamination is not yet clear, however, and extensive experience will be necessary to ascertain the tolerance of catalytic cracking units for salt in feed.

4.6 Water and Steam

4.6.1, 6.2.1, 6.3.1, 2.2.3

Report of Metals Corrosion Investigation, Immersion Tests Five Years Duration, Initiated 1941. Summary and Conclusions. An excerpt of a report, dated May 1950, was based on investigations conducted by the Department of Operation and Maintenance. United States, Panama Canal, Balboa Heights, Canal Zone. H. W. Mundt, L. J. Thompson and S. J. Stacy. *Corrosion*, **7**, No. 2, 51 (1951) Feb.

Results of field immersion exposures of a selected group of welded and bare uncoupled ferrous and non-ferrous metals in Isthmian fresh, brackish and sea waters, for durations of one, three and five years are: a) exclusive of welds, stainless steels and zincs, ipy rates of corrosion are uniform in narrow range based on 5 year exposure results; b) rates of corrosion of different grades of uncoupled zinc do not differ significantly if results of 5-year exposures and all environments considered; c) continuous brackish water environment most aggressive; d) excluding zinc, nonferrous metals show better resistance in sea than in fresh water and least resistance in brackish water; e) welded sections of majority specimens exposed sea water at mean tide in good condition after exposure except: copper-nickel structural and copper-bearing steels and nickel. A table gives spread of ipy values for low alloy steel and wrought iron.

4.6.12, 2.3.4

Water Conditioning Study. A. Gibbon. *World Oil*, **130**, No. 1, 148-149, 157 (1950) Jan.

Studies being made by the Bureau of Mines on methods of conditioning water for water-flooding of reservoirs in the Mid-Continent area indicate that equipment corrosion is a more serious problem in this area than plugging of tubing or oil sands. Frequent routine tests of pH, carbonate stability, alkalinity and free chlorine content are essential and determinations of iron, dissolved oxygen, free carbon dioxide and hydrogen sulfide should also be made. Closed injection systems are applicable if the waters have negligible or very low acid gas concentrations and low iron contents.

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.2, 1.7.1

Objectives and Progress of TP-2 Galvanic Anodes for Cathodic Protection. Walter P. Noser. Humble Pipe Line Co.,

Houston, Texas. *Corrosion*, **7**, No. 1, 1 (1951) Jan.

The Galvanic Anodes Committee is investigating the use of aluminum, magnesium and zinc as galvanic anodes. Effect of such factors as backfill, anode composition and weather are being weighed in tests now under way. A subcommittee has been formed to correlate operating data on anodes installed by companies where testing procedures and measurements differ from committee procedure. Committee memberships are open to companies wishing to enter cooperative tests or furnish data on operating anodes.

5.3 Metallic Coatings

5.3.4, 5.3.1

Corrosion Protection by Spraying Metal Coatings. I. C. FRITZ. *Werkstoffe u. Korrosion*, **1**, Nos. 6 & 7, 261-263 (1950).

A brief review of the Schoop metal-spraying process, dealing with: 1) its development; 2) the causes and avoidance of flaking, porosity, and inclusions in the coatings produced; 3) recent American and German developments in the spraying of metals and plastics by this method; and 4) costs.—MA.

5.4 Non-Metallic Coatings and Paints

5.4.5, 8.4.3

Effective Use of Vinyl Coatings in Control of Oil Field Corrosion. W. H. CLAYTON, Minnesota Mining and Mfg. Co. Paper, N.A.C.E., Midland, Texas. *Pipe Line News*, **21**, No. 10, 29-30 (1949) Oct.

Problems in controlling oil field corrosion with vinyl coatings containing oil-resistant plasticizers are discussed. The use of a practical, economical and safe method of surface preparation will greatly reduce corrosion since most failures appear to be due to inadequate adhesion of the coating to imperfectly cleaned metal. The correlation between the tide range test and sour crude tank protection and a proposed corrosion reduction plan are discussed.

5.4.5, 7.5.5, 8.4.3

Effective Use of Vinyl Coatings in Control of Oil Tank Corrosion. W. J. CLAYTON. Minn. Mining and Mfg. Co. Paper, N.A.C.E. Midland, Texas. *Pipe Line News*, **21**, No. 10, 36-7 (1949) Nov.

Effective use of vinyl coatings in the control of oil tank corrosion requires a practical, safe and economical method of metal preparation and coatings which have been properly plasticized to withstand the embrittling effect of oil or other leaching agents. The advantages and defects of oil based on phenolic resin-nitril rubber primers for vinyl coatings on partially cleaned steel surfaces are discussed. "Wash primer," a combination of vinyl resin, zinc chromate and phosphoric acid solution has eliminated the necessity of sandblasting in many cases. Vinyl-polysulfide rubber and blends of nitrile rubber with vinyl chloride-vinyl acetate gave excellent oil resistant coatings. Florida tide range test for determining the corrosion resistance of vinyl coated steel plates is correlated with conditions existing in sour crude tanks.

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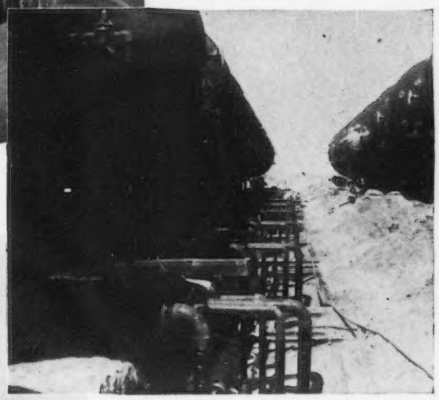

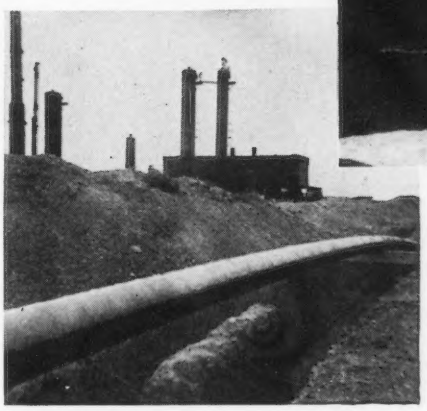

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5.4.5, 3.3.1

Anti-Parasitic Paints. E. CRIVELLI. *Ind. della Vernice*, **4**, No. 41, 171-175 (1950).

A review of anti-fouling, fungicidal, germicidal and insecticidal paints.—RPI.

5.4.5

Triple-Layer Corrosion-Resistant Paint. *Engrs. Digest*, **11**, 412 (1950) Dec.; *J. Brit. Shipbuilding R. A.*, **6**, No. 3, 191 (1951).

A mica-base 3-coat paint system has been developed, which will considerably lengthen the service life of outdoor transformer tanks exposed to sea-coast and industrial atmospheres. In production, it is baked-on for speed, but a modified air-drying finish permits patching of damaged surfaces in the field. The first coat is composed of a vehicle consisting of a combination of modified phenolic and alkyd resins. The pigments used are chiefly zinc chromate and iron oxide. In the second coat, the pigment consists of selected mica flakes that overlap each other in the film, and the vehicle is composed of modified phenolic and thermosetting alkyd resins. The final coat is composed of resins and pigments selected to suit the conditions. Mica increases the heat-stability of the intermediate coat as much as ten times at high temp.—RPI.

5.4.5, 5.3.2

Substitutes for Tin Coatings on Copper Wire. B. W. GONSER. PB. 99165, Microfilm Reel No. 1, Frames 55; Board of Trade, Tech. Inf. & Docs. Unit, ORR. 576/50, 1.

Investigations have been made of metallic and non-metallic coatings as a substitute for tin on copper wire. Commercial grades of alloy-coated wire and electro-plated specimens were tested. Preliminary results with silicone resins showed that copper is attacked at temperatures 200° C. Solderability and joint strength of low tin and tin free alloy coated wires compare favorably with tin coated wires.—RPI.

5.4.5, 7.5.5

Paints for Exterior and Interior Surfaces of Tanks. G. W. OXLEY. Standard Oil Development Co. *Petroleo Interamericano*, **7**, No. 3, 52-53 (1949) Mar.

For sea-water atmosphere, on barges, tankers or other equipment requiring a quick-drying tough coating, a zinc-chromate-and-iron-oxide Bakelite primer is used to advantage. Other alternates are the alkyl red-lead primers or a red-lead-and-oxide primer with the addition of one pound of litharge to each gallon. Present-day paste-aluminum paints have been used extensively for bulk-station tanks and light-gravity refinery tanks. Where corrosive conditions exist on the underside of tank bottoms, heavy applications of cut-back, steam-distilled asphalt have given good protection. The exterior surfaces of steel underground tanks may be protected by a heavy asphalt coating over an inhibitive primer. Recently manufacturers have proposed the use of vinyl paints for protection inside tanks handling sour stocks, gasoline, or other petroleum products where corrosion is being experienced. These may be less satisfactory than gunite cement. Oil-resistant coal-tar paints are also being considered for such service. Phenolic paints, air dried, or even better, heat hardened if baking facilities are available, also have merit as interior tank coatings.

5.4.5

Durability of Outside Paint Work. J. GIFFORD. *Decorator*, **49**, No. 581, 69-70+ (1950).

The factors making for durability of outside paint-work are discussed. The older oil gloss finishes (usually containing white lead) normally fail by chalking and have the merit that the painter can add more oil if the ground is very porous, and can adjust the drier content according to the atmospheric conditions at the time of painting. It is more difficult to obtain a satisfactory finish from such paints than from enamel-type ready-mixed paints, which have better flow and levelling properties. The latter tend to fail by cracking, but are harder and retain their appearance better than the oil gloss types. The false economy of applying too few coats, the need for satisfying paint-thirsty surfaces, proper surface-pretreatment, careful brushing of the paint to obtain a uniform film thickness and the need to allow time for successive coats to dry are stressed. Painting is preferably carried out in the early autumn.—RPI.

5.8 Inhibitors and Passivators

5.8.2, 5.8.4

Alox 600, Alox 707, Alox 937 and Alox 904. Alox Corp., Niagara Falls, N. Y., 1950. Gratis. Alox 600, Alox 937 and Alox 904, publication #QF-408, A-45; Alox 707, publication #TA-467, A-45.

1) Alox 600 is a rust preventive for use on metal surfaces, in cutting and rolling oils and in the preparation of heavy metal salts. Physical and chemical properties are given.

2) Alox 707 is a film forming rust preventive which is applied in solution with a volatile solvent. Coatings of Alox 707 can be removed by ordinary solvents or by a modern degreasing system.

3) Alox 937 and 940 are corrosion inhibitors for use in oil or in volatile solvent solutions. Alox 940 is effective on metals immersed in sea water. Physical and chemical properties are given and recommended uses include use in preservative lubricants, household oils, protection of bright finishes, water displacement agents and cutting oils.

5.8.3, 6.2.5, 4.3.2

On the Inhibitor for the Corrosion by Hydrochloric Acid on High-Chromium Steels. (In English.) HIKOZO ENDO AND SABURO ISIHARA. *Science Reports of the Research Insitutes*, Tohoku University, ser. A, **2**, 209-215 (1950) Apr.

Action of potassium dichromate as inhibitor for corrosion by hydrochloric acid of high-chromium steels was investigated. Molybdenum added to high-chromium steels, so far as it goes into solid solutions, is very effective in lowering the minimum quantity of potassium dichromate and in preventing pit or cavity corrosion of high-chromium steels. Tungsten was not as effective as molybdenum with respect to corrosion resistance of high-chromium steels.—BLR.

5.8.4, 5.8.2, 2.2.7, 2.3.4, 8.4.2

Corrosion Inhibition in Gas Condensate Wells by Intermittent Injection of Alkaline Solutions. CHARLES C. NATHAN. Presented at South Central Region Meeting. National Association of Corrosion Engineers, Corpus Christi, Texas, October 19-20, 1951. *Corrosion*, **7**, No. 11, 397-399 (1951) Nov.

Experiments carried out by personnel of the Producing Research Laboratory of The Texas Company in efforts to reduce corrosion in deep gas condensate wells in the Gulf Coast area in which the casing is mudded off from the tubing indicate:

1. Of two wells with open annuli through which chemicals may be pumped, one well has been treated with sodium carbonate since August 1949 and has shown no measurable corrosion increases in the tubing in two caliper surveys.
2. Wells in the field produce about 1.5 barrels of water per MMCF of gas at their allowable rates of 4.5 MMCF daily. The water contains dissolved carbon dioxide and organic acids. Water collected at the surface has a pH of about 5.5 and contains about 130 PPM of dissolved iron. Lower flow rates produce water with higher pH and greater dissolved iron content.
3. Treatment of the well with 30 gal. per day of solution containing 2.5 lb. sal soda or sodium decahydrate per MMCF of produced gas costs approximately 15-20c per MMCF.
4. Kontol sticks dropped for one year in wells with closed annuli produced no measurable benefit.
5. Alkaline solution pumped intermittently into this well at the rate of 0.5 gal. per min. with sal soda dissolved in 10-20-gal. water had following results: a) At 4 MMCF a day iron content of water dropped rapidly to nearly zero, but rose in two hours to near original value: b)

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At 2 MMCF a day iron content dropped rapidly and is maintained at a very low rate for nearly 8 hours, then in about 4 hours content climbs to original value.

6. Data indicate alkali not being used up by reaction but is flushed from tubing walls by produced water.

Solution can be injected continuously into wells at any depth by another string of pipe.

5.9 Surface Treatment

5.9.2, 5.8.4, 5.9.3

Corrosion, De-Oxidation, Inhibition and Passivation of Metals. J. FRASCH. *Ingenieur,* (Utrecht), **62,** Mk. 87 (1950); *J. Brit. Shipbuilding R. A.,* **6,** No. 1, 37 (1951).

The theory of corrosion and processes for removal of surface oxide layers on iron and steel are discussed. Passivators based on solutions of zinc dichromate in gelatin give protection against atmospheric moisture and, in the case of aluminum, against sea water also. An alcoholic solution of chromium and triethanolamine phosphate cleans aluminum surfaces before spot-welding.—RPI.

5.9.2, 8.4.3

Chemical Cleaning of Process Side Equipment. C. H. GROOM. Dowell, Inc. *Petroleum Eng.,* **22,** No. 5, C48+ (1950) May.

The removal of coke and other organic process-side deposits from refinery equipment is best accomplished by circulating strong oxidizing solutions there through at high velocity. This requires pumps and lines of large capacity. A successful application of the method to cleaning the shell side of slurry condensers on fluid catalytic cracking units is described. It is recommended that heat exchangers be equipped with a perforated tube for introducing cleaning solution directly into the center of the tube bundle.

5.9.2

South Africans Using New Corrosion-Removal Process. *Chem. Eng. News,* **28,** No. 49, 4278 (1950).

Rust and other extraneous surface deposits are removed from complete machines electrolytically in an alkaline bath. Magnesium and aluminum alloys must be protected from attack if present in machinery, and the process has no lasting protective value.—RPI.

5.9.4, 6.4.2

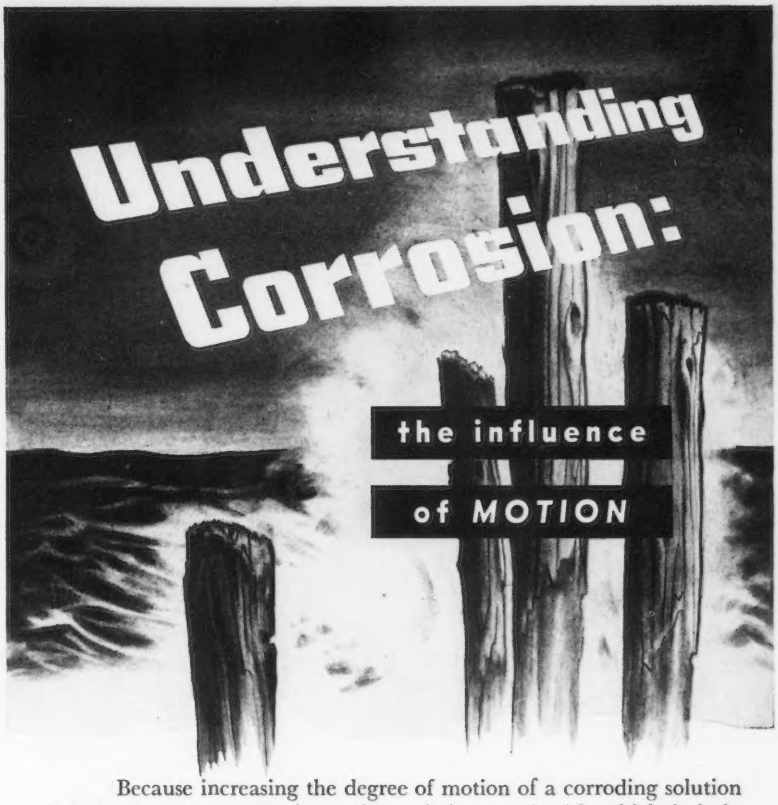
A New Pretreatment Process for Light Alloys: The Application of "Alocrom" to Wash-Boiler Production. R. E. SHAW. *Sheet Metal Ind.,* **26,** No. 265, 1031-1034, 1036 (1949).

Aluminum alloy DTD 606 was used for the production of domestic wash-boilers during the steel shortage, and the "Alocrom" treatment was shown to be the best protective treatment as judged by a boiling soap-solution test. The treatment of boilers by this process is described in some detail.—MA.

5.9.4, 6.4.2

Sealing of Anodized Aluminum Increases Corrosion Resistance. A. E. DURKIN. *The Iron Age* (U.S.A.), **167,** No. 19, 96-98 (1951) May 10.

Anodized aluminum sealed in high purity water with a pH controlled at or near 6



Because increasing the degree of motion of a corroding solution brings more oxygen to the surface of the metal with which it is in contact, such increase has a decided influence on the rate of corrosion. In liquid that may appear quiet, convection currents are nonetheless at work slowly distributing dissolved oxygen throughout the solution. When velocity agitates the liquid-air interface, unsaturated liquid is brought to the surface layer and the oxygen-solution rate rapidly stepped up. At the same time the liquid film on the surface of the metal is thinned so that this increased amount of dissolved oxygen diffuses more readily. Thus the combined effect of more dissolved oxygen conveyed more rapidly to the metal is a marked acceleration of corrosion.

Velocity, too, is often the indirect if not the direct cause of mechanical erosion of metal, for the deterioration it helps bring about results in the formation of corrosion products. In a quiet system these might serve a protective function but with motion a factor they erode readily, leaving already weakened metal exposed to further corrosive attack.

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has approximately 35 percent more corrosion resistance than when it is sealed in ordinary tap water where no pH control is exercised. Sealing alters the anodic coating to a monohydrate aluminum oxide and increases its life and weathering resistance. A varying pH in the seal water tends to nonuniformity in the end product. Also aluminum and copper impurities precipitate on the work as the pH of the sealing water goes below 5.2. If tap water containing between 50 to 100 ppm of dissolved solids is used in sealing, their impurities can become sealed in the anodic coating with resulting adverse effects on the corrosion resistance. If the dissolved solids are organic, they may burn out of the coating if the anodized part operates at temperatures of between 100° and 200° C (212° and 392° F). To determine the effect of pH on the sealing water, anodized parts were sealed in demineralized or deionized water and tap water at pH value between 3.3 and 10.7. The corrosion resistance was determined by the standard salt spray test; 20 percent salt solution at 95° F (35°C). Aluminum alloys 24S and 2S were used, and were anodized by the Alumilite Process. Where necessary, pH variations were made by the addition of either hydrochloric acid or caustic soda. Results showed that panels sealed in demineralized water are more corrosion resistant than those sealed in tap water at comparable pH values. The optimum corrosion resistance was obtained using demineralized water at pH values near 6. Panels sealed in tap water had the best corrosion resistance when the pH was close to 6. Results indicate that, while demineralized water is a better sealing medium than tap water, tap water can be used effectively where high purity water is not available if its pH is controlled as close to 6 as possible.—ALL.

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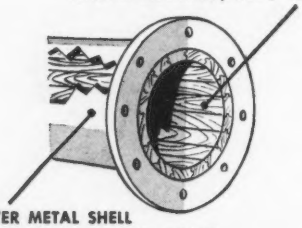

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5.9.4, 5.2.2

Alodine Process, Galvanic Protection For Aluminum (Le procédé Alodine, protection galvanique de l'aluminium). C. Hess. *Rev. aluminium* (France), **28,** No. 174, 44-50 (1951) Feb.

The Alodine process is a surface treatment for aluminum and its alloys designed to facilitate the adhesion of paints. The articles are immersed in an acid bath containing essentially, phosphate, fluoride and chromate ions, in due proportions; the treatment is carried out without the use of electric current. The mechanism of the operation appears to consist in the formation of a complex coating of alumina and aluminum salts of the acids mentioned above. Laboratory tests have shown that this coating provides an interesting protection against corrosion.

The various operations of the process are as follows: 1) the surface is thoroughly cleaned; 2) it is thoroughly rinsed to free it from all traces of alkali; 3) it is treated in the Alodine solution; 4) to provide maximum corrosion resistance (without painting) it is dried at high temperature, without rinsing; 5) if the metal is to be painted, it is rinsed with clear water; 6) it is rinsed twice in a dilute solution of mineral acids; 7) it is allowed to dry at room temperature.—ALL.

5.10 Other

5.10, 6.4.2

New Low-Cost Jacketing Cuts Maintenance on Insulated Lines. *Chem. Eng. Progress* (U.S.A.), **46,** No. 11, 35 (1950) Nov.

The Childers Manufacturing Co. of Houston has developed a permanent-type aluminum jacketing to protect outdoor lines in chemical plants and refineries. Aluminum sheet 0.006 in. thick is the weather-protecting sheath of the jacketing. It is ribbed for extra strength and to facilitate forming around the line. The jacketing is available in rolls that are four feet wide and either 100 feet or 200 feet long. It is light and flexible to handle, and no roll forming is required as with heavy, un-crimped material. Positive protection for the aluminum when it is used with alkaline insulating materials is provided by a moisture barrier attached to the back of the jacketing.—ALL.

6. MATERIALS OF CONSTRUCTION

6.1 General

6.1, 8.8.1, 5.4.5

Materials of Construction for Handling Sulfuric Acid TP-5A—Materials, Handling and Manufacturing Sulfuric Acid. Spencer W. Shepard. *Corrosion,* **7,** No. 8, 279-282 (1951) Aug.

Sulfuric acid has corroded more metal both intentionally and unintentionally than all other commercial acids combined. Application of some of the fundamental factors that govern corrosion rates will minimize attack in many cases. Inhibitors will stifle attack in others. Some of the recently developed organic materials are practically inert over wide concentrations. With the right material of construction in the right place most sulfuric acid corrosion problems can be practically eliminated.

6.1, 1.3

New Corrosion-Resistant Materials in Use Abroad (Outside Germany). I.—V. (In German.) Erich Franke. *Werkstoffe u. Korrosion,* **1,** Nos. 4, 5, 8, 9, and 12; pages 136-143, 171-178, 305-308, 349-357 and 497-506 (1950) Apr., May, Aug., Sept., Dec.

A review. The production, the mechanical and corrosion resistant properties, and the applications of materials are described in some detail. I. Titanium. II. Special high-carbon stainless steels, and Chlorimet 2 (nickel 63, molybdenum 32, iron 3, and silicon 1 percent) and Chlorimet 3 (nickel 60, molybdenum 18, chromium 18, iron 3, and silicon 1 percent) III. Langalloy 4R (nickel 63, molybdenum 30, iron 5, manganese 0.75, and silicon 0.75), Langalloy 5R (nickel 56, molybdenum 17, chromium 15, iron 5, tungsten 5, manganese 0.75, and silicon 0.75), and Langalloy 6R (nickel 85, silicon 10, and copper 3). IV. Low-iron copper-nickel alloys for condenser tubes. V. Gives production, physical properties, chemical components, and successive laboratory application of two new compounds showing resistance to corrosion, polymers of tetrafluoroethylene and chlorotrifluoroethylene.

6.2 Ferrous Metals and Alloys

6.2.5, 4.4.2, 8.8.1

Corrosion of Bubble Caps in a Chemical Plant. Clyde W. Day, R. C. Scheuler, and E. V. Kunkel. *Corrosion* (News Section), **7,** 1 (1951) Feb.

Illustrates and briefly discusses above corrosion of Types 316 and 317 stainless steel upon exposure to various concentrations of acetic acid at 200°-300° F.—BLR.

6.2.5, 4.3.2, 3.4.8

The Behavior of The Chromium Nickel Stainless Steels in Sulfuric Acid. George C. Kiefer and William G. Renshaw. Allegheny Ludlum Steel Corporation, Brackenridge, Pa. Paper Sixth Ann. Conf. Natl. Assoc. Corrosion Engrs., St. Louis, Mo., April 4-7, 1950. *Corrosion,* **6,** No. 8, 235-244 (1950) Aug.

This article shows the corrosion rate of four commercial types of chromium nickel stainless steels and one special type in sulfuric acid of varying concentration from 0 to 95 percent, at four temperatures, 100° F (38° C), 150° F (65° C), 175° F (80° C), 200° F (93° C). The effect of the additions of various sulfates and oxidizing agents to the acid on the corrosion rates is also shown. All samples were tested in an activated state and the data indicate the acid concentration and temperature, in which the metal becomes and remains passive. At temperatures about 150° F (65° C), all of the steels remain active in practically all acid concentrations and corrosion rates are high. Below this temperature, the molybdenum bearing steels, Types 316 and 317, are most resistant and increasing chromium content, Type 310, has some effect in lowering the corrosion rate. The addition of copper to the molybdenum bearing steels improves

resistance to a marked degree, although these steels appear to behave similarly to copper and copper-nickel alloys in that they do not show a sharp passive-active boundary. The addition of various inorganic sulfates to sulfuric acid causes a marked lowering of corrosion rates. There is an indication that sulfates of metals below chromium in the E. M. F. series completely inhibit attack and provide a passive condition. The addition of oxidizing agents, such as nitric or chromic acid and dichromates also completely inhibits attack.

6.2.6

Atmospheric Rusting of Iron. G. SCHIKORR. *Arch. Metallkunde*, **3**, 76-9 (1949).

In cold weather, rust formation is considerably reduced, but the effect of extended cold periods on the overall corrosion of exposed iron is slight. This is attributed to the continued sulfur-compound absorption which resumes destructive action upon return of warmer weather. When filter paper was wrapped around iron, atmospheric corrosion was reduced to less than one half. This is interpreted as proof for the predominant part played by gaseous sulfur compounds dissolved in rain.

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.4, 6.3.3, 3.5.9

Quarterly Progress Report on Alloys For High-Temperature Service, to Office of Naval Research. E. E. FLETCHER, A. R. ELSEA, A. B. WESTERMAN, AND G. K. MANNIN. Battelle Memorial Inst., June 16, 1950. 21 p. (NP-1725).

The investigation of the effects of tungsten and molybdenum on the α-β transformation temperature range in cobalt-chromium alloys was continued. Work was continued on the production of satisfactory carbon bearing ternary alloys for use in determining the effect of carbon on the α-β transformation temperature range. Early tests resulted in excessive carbon losses during homogenization. The heat-treating technique and apparatus were modified; as a result, several carbon bearing alloys have now been homogenized with only a slight loss of carbon. Commercially produced alloys, Stellite 21 type, of four different analyses have been homogenized and the carbon was retained quite satisfactorily. Partial melting occurred when the usual homogenizing treatment of 80 hours at 1260° C was used. Some modification of this treatment may be required for the Vitallium-type alloys and for the carbon bearing ternary alloys, especially those with relatively high carbon contents. Fourteen creep-rupture tests at 780°, 915°, and 1000° C have been completed on cobalt-chromium alloys containing nitrogen.—NSA.

6.3.6, 8.1.2, 4.2.6

Historic Church's Copper Roof Good After 213 Years. A. W. TRACY, Assistant Metallurgist, Corrosion Research Laboratory. The American Brass Company, Waterbury, Conn. *Corrosion*, **7**, No. 11, 373-375 (1951) Nov.

An examination of English-made copper sheets taken from the roof of Christ Church, Philadelphia, Pa. after 213

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years' exposure shows a weathering loss of 0.007-inch at thinnest areas, equivalent to a corrosion rate of 0.000033-inch per year. It is believed the essentially rural character of the atmosphere during early exposure of these sheets has contributed to their life. Recent corrosion tests on copper sheets in an industrial atmosphere show somewhat higher rates. Rockwell hardness of 15T 61 to 63 indicated the sheets on the church had been finished in a slight temper. Screws driven through the center of some sheets twenty years ago restricted expansion and contraction and caused fatigue cracks. Some of the 3-inch wrought iron nails, originally used to fasten the copper pans to the roof boards had corroded through at the roof line, possibly as a result of condensation.

6.3.15, 4.3.2, 2.3.4

The Corrosion of Titanium in Acids—The Rate of Dissolution in Sulfuric, Hydrochloric, Hydrobromic and Hydroiodic Acids. M. E. STRAUMANIS AND P. C. CHEN. School of Mines and Metallurgy, The University of Missouri. *Corrosion*, **7**, No. 7, 229-237 (1951) July.

It can be shown that the dissolution of titanium in sulfuric, hydrochloric, hydrobromic and hydroiodic acids must proceed according to the reaction $Ti^{0} \rightarrow Ti^{3+} + 3e$, exactly as when titanium dissolves in hydrofluoric acid. The rate of dissolution of Bureau of Mines titanium in sulfuric and hydrochloric acids below 2 normal is extremely low. The dissolution rate is still lower in hydrobromic acid of all concentrations. Hydroiodic acid does not react at all with purest titanium. Its resistivity can be explained by the formation of protective layers, which are easily dissolved by hydrofluoric acid. Therefore, small amounts of ammonium fluoride, added to the above mentioned acids accelerate greatly the rate of dissolution of titanium even in hydroiodic acid. The presence of protective films on the surface of titanium can be demonstrated by potential and current measurements. The potential of titanium in sulfuric and hydrochloric acids becomes less noble (more anodic) in time, approaching a limiting potential. It also becomes less noble with increasing concentration of the acid. The potential of titanium is +0.26 volt in 1 normal, and —0.353 and —0.342 volt in 6 normal sulfuric or hydrochloric acid respectively while in hydrofluoric acid it is —0.77 volt. Hence, titanium does not displace noble metals from their salt solutions until hydrofluoric acid or soluble fluorides are added to the above mentioned acids. The potential of titanium becomes more negative with widening of the pores of the films. This, in turn depends on the nature of the film and solvent. The film on titanium shows the property of selfregeneration.

The rate of dissolution of Bureau of Mines titanium in sulfuric acid stronger than 2 normal increases with the concentration. The metal shows a tendency for passivation after a time lapse. Remington Arms titanium does not possess this property. The rate of dissolution of titanium is affected by impurities. It can be shown that the behavior of this metal in acids can be explained by the concept of local cells in connection with the presence of protective films on the surface of titanium.

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2, 6.3.10, 6.3.6, 8.4.1

Corrosion Problems in the Modern By-Product Coke Plant. E. A. TICE. Corrosion Engineering Section, The International Nickel Co., Inc., New York, New York. *Corrosion*, **7**, No. 4, 127-128 (1951) April.

Data are presented supplementary to that included in the basic article published in CORROSION, 7, No. 3, 76-84 (1951) Mar., giving results of spool tests. Results further substantiate those reported in basic paper. Superior corrosion resistance is reported for lead in light oil acid washing service. Linings in plant where tests have been made required considerable maintenance because of material's poor mechanical properties. Four materials appear to have merit corrosionwise: Carpenter 20, Monel, 10 percent aluminum bronze and silicon bronze. Design would have to allow for corrosion losses on the order of 0.2 to 0.3 inches per year.

6.4.2

Influence of Additions of Zinc and Tin to Aluminum. G. CAMINADE. *Fonderie* (France), No. 55, 2134 (1950).

The findings of recent work on the effect of the addition of zinc and tin to aluminum are reviewed. At the present time, foundry alloys contain only small amounts of zinc, which has little effect on the properties of the alloys and the tolerances for the zinc content are large. The advantages of adding tin are negligible compared with the increase in the hot shortness and the reduction in the resistance to corrosion that results.—BLR.

6.4.2

Modest But Varied British Light Metal Trials. *Oil Forum*, **4**, No. 3, 109-110 (1950) Mar.

Although British engineering circles believe economic utilization of aluminum is centered primarily in the transportation business, applications in the petroleum industry other than for tank-ship superstructures are believed to have great promise in regard to corrosion elimination. The steady reduction in cost of primary aluminum production as compared to high steel prices may cause potentially expanded use of aluminum. Aluminum alloy piping has been tested for oil transmission lines and various auxillary equipment in refineries. Aluminum tanks and other containers have been developed, and extensive use has been made of aluminum alloy electrical conduit in oilfield and refinery installations and for anodic protection of pipelines. Alloys selected for these applications are mainly of the magnesium-silicide types, which have adequate corrosion resistance, high strength and good weldability. Experimental applications of aluminum in Britain have involved the production of extruded pipe and construction in the field has been either by argon-shield arc welding, bolting of flanges, or use of couplings. One installation is of bolted construction, the tubing having been expanded into flanges for the purpose. It was originally installed as a crude oil discharge line at the Purfleet jetty of Anglo-American Oil Co., Ltd., and has been used for the last 14 months as a product loading line to solve a particular corrosion problem encountered in handling solvent naptha. Pressures exceeding 200 psi have been carried, and tests indicate maintenance is a negligible factor. The Royal Dutch-Shell has ordered 1,000 feet of 4-in. OD aluminum-magnesium tubing in standard 30 foot lengths for its Venezuelan operations. The pipe is to be laid as a crude oil line under the waters of Lake Maracaibo to test its corrosion resistance compared with standard line pipe. W. P. Butterfield Ltd. is using aluminum for tanks to increase the effective payload of road transports hauling refined products.—ALL.

6.5 Metals Multiple or Combined

6.5, 6.7.1

Production of Weather- and Fire-Proof Paper, Particularly for Camouflage Purposes. I. G. FARBENINDUSTRIE. PB. 25616, Frame 276; Prev. Det. Abs., 6, W 30 (1949).

Paper is first impregnated with materials such as ammonium salts, alkali borates or silicates, then covered with a urea formaldehyde condensation product and finally coated with a water-glass compound, during or after the hardening of the urea formaldehyde layer.—RPI.

6.5

Uses of the Rare Metals. (In German.) H. Blumfeldt. *Metall.*, **4**, 300-303 (1950) July.

Briefly outlines mechanical and physical properties, occurrence and uses of each of the following: lithium, beryllium, sodium, copper, titanium, gallium, germanium, rubidium, zirconium, niobium (columbium), ruthenium, rhodium, palladium, cadmium, indium, cesium, barium, cerium, tantalum, rhenium, osmium, iridium, thallium and bismuth.—BLR.

6.6 Non-Metallic Materials

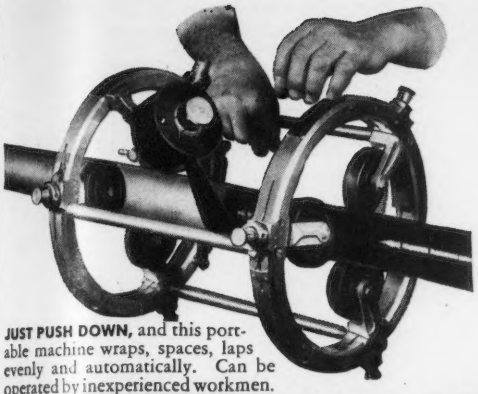
6.6.5, 8.4.3

Concrete Casing. A New Tool To Fight Corrosion. *Petroleo Interamericano*, **7**, No. 4, 42-43 (1949) April.

Centrifugally formed reinforced-concrete is one of the recent additions to the techniques designed for combating corrosion in casing. Although more expensive than steel pipe, volume-production may materially reduce this cost. The pipe is provided in 14-foot lengths, having a 10-in. inside diameter and 2-in. walls. Reinforcing is provided by nine longitudinally placed ⅜-in. steel rods. Alloy steel corrosion-resistant shoulder collars grooved for a round ring-gasket are welded to the reinforcement to provide an integral unit. The pipe was originally designed to be run under compression on drill pipe, but modification of joint design now permits strings up to 175 feet to be run in the conventional manner in tension with elevators and slips. Sections have a compressive strength of 5,500 lb.; theoretical maximum setting depth for this size casing is 2,500 feet. The technique for running the casing is outlined. The string is cemented in the conventional manner. The concrete pipe was invented by C. E. Knox.

6.6.6

Corrosion Resistance of Pure Alumina



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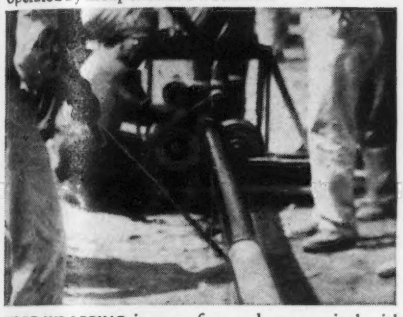

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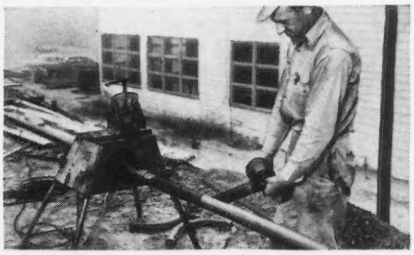

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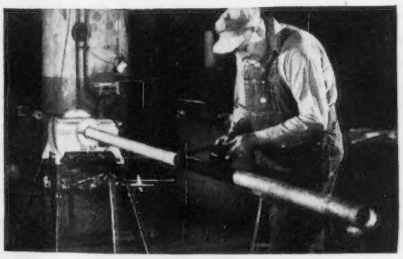

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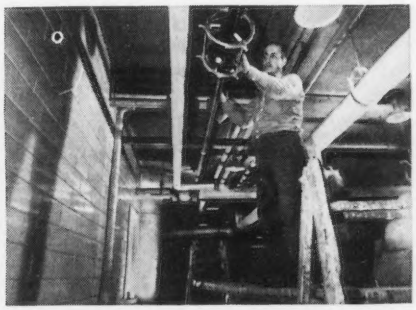

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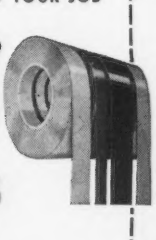

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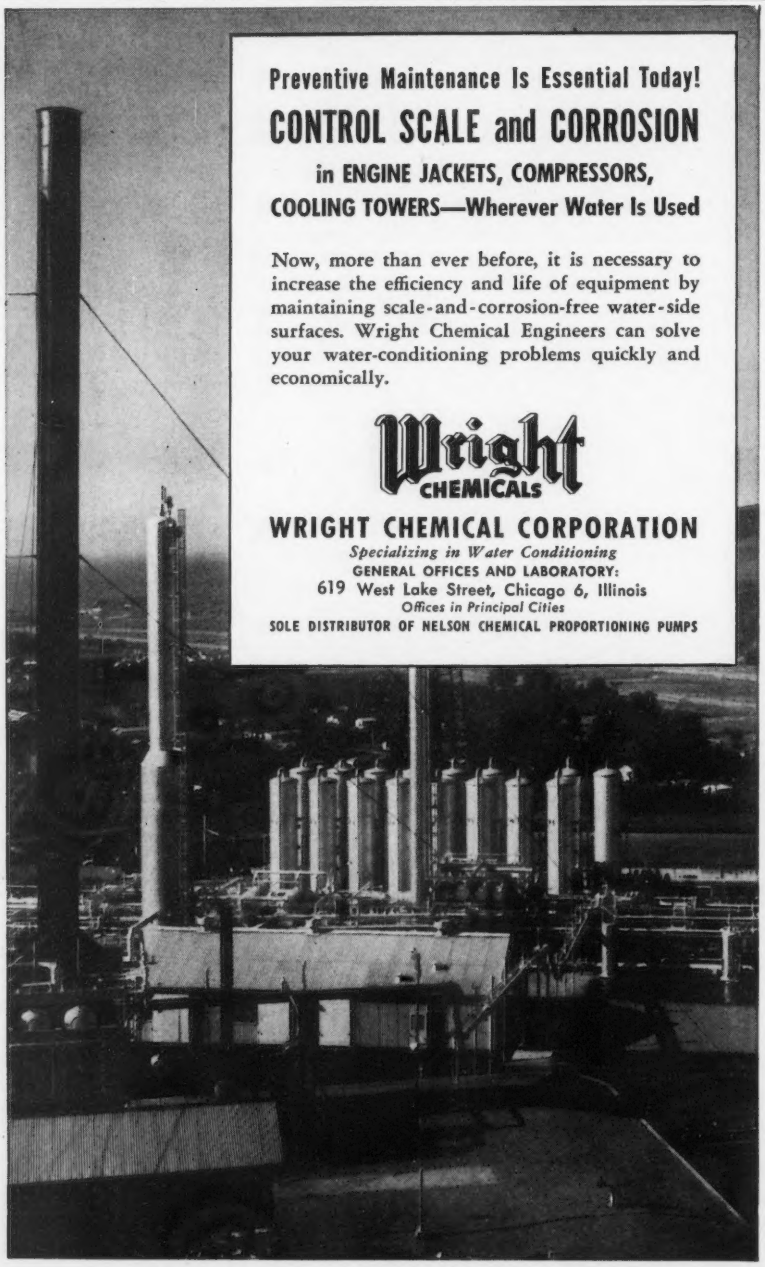
as a Glass Refractory. FRANK DAY, JR., AND J. P. AMBROSONE. *J. Am. Ceramic Soc.*, **34**, 163-164 (1951) May.

Small corrosion-test samples were cut from non-porous, single-crystal, gem-and-bearing-type sapphire boules. These, along with similar samples of "Corhart ZAC" refractory, were placed in contact with a common lime glass for various times at temperatures between 1400° and 1550° C. Results are charted and discussed.—BLR.

6.6.8, 8.4.3, 4.6.12

Plastic Tubing in Salt Water Disposal Well. A. GIBBON. *World Oil*, **129**, No. 8, 151-2, 154 (1949) Nov.

A 3387 foot string of corrosion-resistant, all plastic tubing has been successfully run in a Western Kansas salt water disposal well. The tubing weighed only 1.5 tons, compared with 17 tons for a comparable 3-inch cement lined steel tube. Plastic tubing resists ageing, weathering, and chemical attack by most acids, alkalis, salts, soils and hydrocarbons encountered in crude oil production. Its compressive, impact and flexural strength are sufficient for normal gravity and low pressure flow of sweet or sour crude, salt or fresh water, gasoline, or raw gas. The slick internal surface of the pipe reduces both flow friction and the deposition of solids thereon. Leak-proof couplings are provided by "cold weld" cemented sleeve joints. The plastic is "Carlon B," a special grade of cellulose butyrate-acetate. Physical property data are given for the plastic and the pipe in standard sizes. The manufacture, care and handling, limitations and make-up of the pipe are briefly described.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6.7 Duplex Materials

6.7.2, 3.4.6, 3.5.9

Cermet Oxidation Studies. WILLIAM B. CRANDALL, Alfred University. Office of Naval Research. *Research Reviews*, October 1950, p. 1-4, diagrs.

Cermets are metal-ceramic combinations designed to combine the strength and thermal-shock resistance of metal with the refractoriness of ceramic. Since the desirable properties of metal are nullified if it oxidizes, the extent to which a cermet resists oxygen attack is a measure of its usefulness at high temperatures.

This oxidation process was studied by measuring both the weight gain of a cermet and the thickness of the oxidized layer as functions of time. On heating, there is an initial rapid gain in specimen weight; then weight increase proceeds more slowly. The period of rapid gain corresponds to the time during which the oxide layer is penetrating the specimen. The rate of oxidation or oxide penetration of a cermet appears to decrease as the concentration of the metal increases and to increase with the porosity of cermet. The shape of the specimen also influences the oxidation rate. In addition, temperature, oxidation rate of the metal component, particle size and partial pressure of oxygen contribute to the oxidation characteristics of the cermet.

The observed behavior is explained by the existence of an intimate equilibrium between the factors that affect the rate of oxygen diffusion into the cermet and the factors that affect the rate at which oxygen is removed from the pores of the cermet.

For these oxidation resistance studies a balance was constructed that automatically weighed and recorded the weight of the specimen continuously during heating. It was found that intermittent weighing does not account for the entire theoretical percentage increase in weight during oxidation. To determine the thickness of the oxide layer, specimens similar to those used in the weight study were cut in half along the cylinder axis and the oxide layer penetration in millimeters was noted after various periods of exposure to air at elevated temperatures.

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

The Problem of Materials for Marine Gas Turbines. *Metallurgia*, **42**, No. 248, 1-2 (1950) June.

It was shown both with ash produced by the combustion of vanadium-bearing fuel oils and with synthetic ash consisting of vanadium pentoxide and sodium sulfate, that in its molten state the ash rapidly attacks all the well known gas turbine steels and alloys. The higher the temperature, the greater is the rate of attack. The possibilities of protective coatings have so far proved disappointing.—INCO.

7.1, 3.5.9

The All-Important Spark Plug. G. L. FURMAN AND B. CORRIGAN, Texas Co. *Aero Digest*, **59**, No. 4, 20-1, 92-4 (1949) Oct.

The construction of the common spark-plug is described. The fine-wire platinum type electrode has excellent corrosion resistance and produces more exposed spark; it also has a lower heat retention and therefore can be heated and cooled more rapidly, tending to follow the thermal fluctuations of the combustion cycle. TEL in gasoline may cause a grayish-yellow-to-brown powdery deposit on the insulator and electrode. Cold plug operation is indicated by soot deposits on the insulator and plug body. Fouling from oil pumping produces a hard, shiny, sometimes wet deposit on the firing end of the plug. Too hot an operation is evidenced by a dry, white or light-tan insulator, while the electrodes reveal burning. Hot operating lessens deposits from TEL-containing fuels. Uneven color of "over-heated" plugs indicates blow-by. Gas leakage is revealed by vertical, streaky sooting of the external glazed insulator of the plug.

7.1, 5.8.3

Evaluation of Engine Preservative Oils. Part II. H. SELLEI, Nox-Rust Chem. Corp. *Sci. Lubrication*, **1**, No. 7, 11-12 (1949) Nov.

The theoretical background of corrosion prevention in the internal combustion engine is reviewed, with special emphasis on the classification of corrosion inhibitors, the role of adsorption, the use of polar type rust inhibitors and methods for the measurement of rust. 26 references.

7.1, 3.5.3, 4.4.9

Oil Can Control Wear. R. E. JEFFREY, JR. AND J. M. PLANTTEBER. Shell Oil Co., San Francisco, Calif. Paper, 5th Ann. Conf., Nat'l. Assoc. Corrosion Engrs., Cincinnati, Ohio, Apr. 11-14, 1949. *Corrosion*, **6**, No. 4, 115-119 (1950) Apr.

A new development in engine lubricants has demonstrated that oil can control wear, where that wear is largely due to corrosion. Corrosion of cylinder walls and rings has long been known to be a factor in engine wear, but only a minor one. Therefore, little was done about it from the oil point of view until recently, development being aimed at the recognized major problems of alloy bearing corrosion, ring sticking and engine deposits.

A thorough study of engine wear has been undertaken during the last few years, to determine what could be done to minimize wear through engine oil development. The effect of the corrosive action of combustion products was found to be great in the case of certain high speed Diesel engine applications, particularly. Operating conditions and the fuel used were found to be important factors in those applications. Stationary engine operation with a given fuel is usually much more severe than operation of the same engine in a vehicle. It has been found that while fuels relatively high in sulfur are associated with high wear rates, there are many operating conditions where fuels relatively low in sulfur are associated with high wear as well. Where corrosive wear conditions prevail, Heavy Duty Type oils were found to offer but little aid in wear reduction.

A new engine lubricating oil has been developed which has been found to reduce wear to as much as one-tenth of that usually found in certain Diesel engine applications. Repeated field service tests in marine and stationary engines have confirmed this. In addition, significant reduction in engine deposits has been found with the new lubricant. In high specific output Diesel engines where ring sticking was a problem with Heavy Duty Type oils, the new lubricant has been found to give excellent results.

Because of the great demand for Diesel fuel during the last few years, it has been necessary to use components higher in sulfur in order to provide the quantities required. The development of the new lubricant is therefore particularly timely. It holds definite promise of vastly improved operation for pipe line pumping engines where the fuel used is the crude oil pumped through the line. Tests in one make of engine have been completed successfully using a heavy (25° API gravity) crude oil of 2.17 percent sulfur. These exploratory tests of short duration were sufficiently favorable that serious consideration can be given to the use of heavy fuels on a commercial basis in this engine if the new lubricant is used.

7.3 Pumps, Compressors, Propellers, Impellers

7.3, 6.4.2, 5.10

Overlaying with Aluminum-Bronze Electrodes. J. A. CUNNINGHAM. *The Welding J.*, **28**, 1162-1165 (1949) Dec.

Where metal-to-metal contact is involved, hard grades of aluminum-bronze electrodes (160 to 300 Brinell) are rapidly assuming an important place in overlaying new and worn steel parts because they provide low-friction, non-seizing surfaces and wear remarkably well. Fur-

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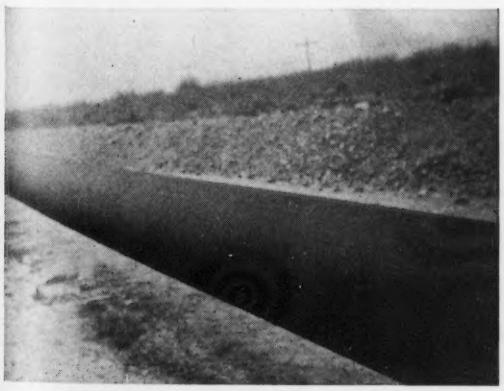

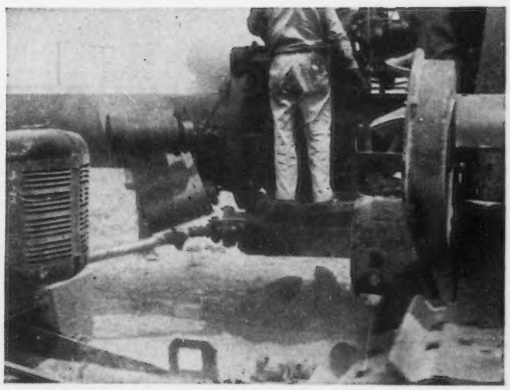

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ther, aluminum-bronze electrodes can be applied to high-carbon, alloy or tool steel without danger of spalling off or cracking the parent metal. Most grades of cast iron and bronze can also be overlayed. Overlays are successful on difficult-to-weld metals, such as large tool steel, medium carbon or cast-iron gears, because bronze inherently possesses a characteristic of penetrating into the pores of the metal and bonding firmly. Also, since aluminum bronze melts at approximately 1,950 deg. F, 700 degrees less than steel, it can be applied rapidly without materially affecting the heat treatment in the parent metal and the deposit feathers out as welded and leaves no craters when the arc is broken. Much of the long wearing characteristics of aluminum bronze can be attributed to the high polish attained by the bronze as it wears. Excellent life is obtained even when the bronze overlay is working against hardened steel parts due to the non-seizing effect of dissimilar metals working against each other. Bronze overlaid shafts operating against pump packing last three to six times longer than the original shafting which is usually harder than the bronze overlay. It is interesting to note also that packing is tremendously increased when shafts are overlayed with hard aluminum bronze because bronze wears smoothly and does not pit or corrode. When shafts are to be operated against bronze bearings, bronze overlays are not recommended because the dissimilar metal effect would not be present.—TIME.

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7.4 Heat Exchangers

7.4.1, 5.9.2, 5.9.3

Symposium on Fouling and Cleaning of Heat Exchange Equipment. L. F. Collins, W. L. Webb, R. L. Clapper, and R. M. Armstrong. Paper, A.S.M.E. Annual Meeting, Nov. 29-Dec. 3, 1948.

The following papers are included: 1) "Outline of Problems — with Emphasis on Water Circuits," L. F. Collins. The formation and prevention of scales, sludges, slimes and barnacles on the coolant side of fresh-water cooled heat exchangers is discussed. 2) "Fouling and Cleaning of Unfired Heat Transfer Equipment in Stream Power Plants," W. L. Webb. Surface condensers usually present the most serious problem. Cleaning methods and policy are discussed from the viewpoint of fuel savings vs. downtime costs. 3) "Fouling and Cleaning Problems Pertaining to Process Industries, R. L. Clapper. Fouling factors for liquids which are not reasonably clean are the most indefinite of all design factors. An abnormal dirt factor may be due to fouling before the exchanger is used, to heat-exchanger design and arrangement, to decreased liquid flow, or to excess treatment of the vapor, liquid, or gas before entering the heat exchanger. Suggestions for cleaning precautions are made and a table is given (in the original) of the various exchanger duties where unexpected heavy dirt accumulations may occur. 4) "Influence of Fouling on Design of Heat Exchangers," R. M. Armstrong.

7.5 Containers

7.5.5, 4.4.9

Selection and Maintenance of Tanks In Sulfide Areas. H. D. Murray. Texas Co. Paper, API Prod. Div., Southwest. Distr., Galveston, Mar. 9-11, 1949. *World Oil*, **128**, No. 13, 161-162+ (1949) Apr.

The factors to be considered in selecting tanks or treaters for lease operations in the Permian Basin or in other sulfide areas include: the oil and water production rates, the conservation of the lighter hydrocarbons, the corrosion resistance of the material, its salvage value, the operators' policies or standards design changes, the type of material and the unit cost. The advantages and disadvantages of wooden, bolted steel and shop welded steel tanks are compared. Both aluminum and galvanized wrought iron decks for bolted tanks have given excellent corrosion resistance. The cone-bottom tanks have reduced corrosion, since the corrosive sediment may be easily drawn off through a sump installed at the bottom. Synthetic lap joint gaskets and washers have reduced greatly seepage along the bolts. Maintenance and safety problems are considered.

7.7 Electrical, Telephone and Radio

7.7, 1.2.1

An Analysis of the Effect of the Life of Hardware Items of Overhead Pole Line Structures on Overall Annual Costs. E. W. Oesterreich, Duquesne Light Co. *Edison Elec. Inst. Bull.*, **18**, No. 8, 307-319 (1950) Aug.

In order to analyze the problem of the cost of overhead line supporting struc-

tures, the basic characteristics of present-day structures are examined. The examination includes a description of pole line structures, deterioration factors, reduced first cost of line extension, and wartime operating experience. The analysis is divided into three parts: analysis of costs for a hypothetical system; example of hardware design possibilities; and practical applications to an existing system. It was shown that, while the cost of the hardware is only of secondary importance in controlling total costs, the life of the material items determines the degree of coordination of design, the number of replacements to be made, and the labor and drayage expenditures to be incurred. Data indicate that no method for extending the life of the bolt is as economical as the use of corrosion-resistant material. This is particularly true if the characteristic of corrosion resistance is accompanied by an increase of strength. Among other general conclusions it was found that a reduction in annual costs would be attained if wood pole structures were designed so that all parts of the structure would have a life expectancy as long or longer than the pole. Further, all structures should be rebuilt at time of pole renewal for complete coordination, even though the adoption of this principle requires the replacement of parts which have been in service for a comparatively short time.—TDD.

8. INDUSTRIES

8.3 Group 3

8.3.5

Where Corrosion Is Most Severe. St. John and Co. *Die Castings*, **8**, No. 11, 22-23+ (1950) Nov.

Describes die-cast aluminum hubs and die-cast zinc caps for wheels on hand trucks used in the meat packing industry. They must withstand heat and cold and exposure to grease, oil, animal fats, blood and brine.—BNF.

8.3.5, 8.8.2, 6.1, 1.2.2

Corrosion Resistant Equipment for the Corn Refining Industry. R. W. Flournoy. Chemical Division, Corn Products Refining Co., Argo, Ill. Paper 6th Ann. Conf. Nat'l. Assoc. Corrosion Engrs., St. Louis, Mo., April 4-7, 1950. *Corrosion*, **7**, No. 4, 129-133 (1951) April.

A general process flow sheet of the corn refining industry is shown to indicate the process steps for which corrosion data were determined. Corrosion data for starch, dextrose and by-product manufacture were taken from field and laboratory corrosion tests. Special techniques for determining the effect of pitting, intergranular corrosion of welds and applied stress were used for some materials tested. Determination of metallic contamination by a corrosion test is explained. The inclusion of economic factors in calculation of a corrosion cost index was employed in evaluating the corrosion data.

Corrosion rates and corrosion cost index values are shown in tables for a number of process steps in the corn refining industry. The materials which indicated satisfactory values are separated from the materials which did not indicate satisfactory service in the environment. The corrosion data are confirmed in some tests by actual experi-

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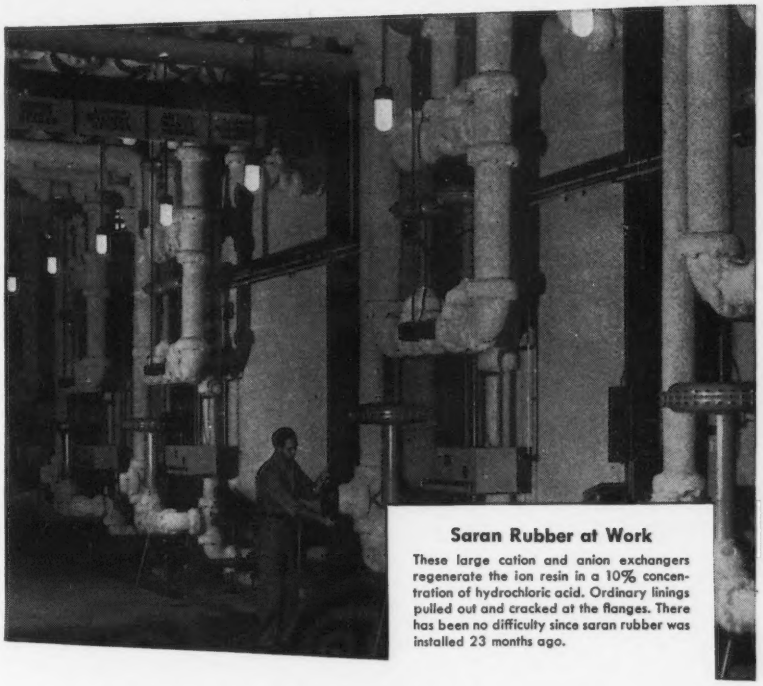

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ences with plant equipment. Limiting values for corrosion rates and corrosion cost index are shown.

The corrosion data are summarized to show the materials which may be considered corrosion resistant for certain corn refining processes. The materials are shown in the order of preference. Factors of physical characteristics and availability are shown for some materials.

8.4 Group 4

8.4.3

Corrosion Control in the Lake Maracaibo Oil Fields. J. H. ZAUNER, Creole Petroleum Corp. *World Oil,* **131,** No. 3, 229-230 (1950) Aug.

The direct losses attributable to the corrosion of the Lake Maracaibo oil gathering system amount to more than $1 million annually. A description of the lake and gathering system, types of corrosion encountered and service records of equipment are given. The use of insulating flanges to reduce galvanic corrosion, various types of line coatings and methods of protecting marine craft are presented.

8.4.2

Corrosion Problems in Gas Plant and Cycling Operations. J. H. NASHKE. Humble Oil and Refining Co. Paper, N.G.A.A., Southern Regional Meet., Tyler, Texas, Oct. 14, 1949. Summary, *Petroleum Processing,* **4,** 1277-8 (1949) Nov.

Many recommendations are given for preventing corrosion in boilers, steam and water piping, fittings, vessels and exchangers in natural gasoline utility plants.

8.4.3, 5.9.2

Chemical Circulation Methods in Cleaning and Descaling Petroleum Processing Equipment. V. BOWES, Oakite Products, Inc. *Petroleum Refiner,* **28,** No. 10, 121-124 (1949) Oct.

Circulation of specialized chemical solutions is a rapid, effective method of cleaning petroleum processing equipment. Dismantling is avoided; thorough and uniform cleaning is achieved with minimum abrasion; the metal surfaces are left smooth; time, material and costs are saved. General types of chemicals for various types of equipment are suggested, but the advice of cleaning materials manufacturers' service representatives should be secured.

8.4.3, 5.7.1, 7.6.9

Thermofor Catalytic Cracking Gas Plant Corrosion Survey. CHRISTOPHER A. MURRAY. Paper presented, South Central Regional Meeting, Nat'l. Assoc. Corrosion Engrs., Dallas, Texas, October 3-4, 1949. *Corrosion,* **7,** No. 3, 98-108 (1951) Mar.

Severe corrosion has been experienced in a Thermofor catalytic cracking gas plant over several years. Representative inspection findings are outlined. A complete chemical survey of gas plant streams for amount and type of corrosives, together with water present, is given. Ammonia and hydrogen sulfide are indicated the principal corrosives present. These have caused corrosion of overhead condensing equipment. Some ammonia acid salts are present which have dissociated at reboiler temperatures to give acid conditions which have caused rapid attack of reboiler tubes. Measures are suggested to remove water, which will also remove the principal corrosive constituents at appropriate points in the system. Possible places for chemical injection are suggested to neutralize any traces of remaining corrosives.

8.4.1, 6.1

Corrosion Problems in The Modern By-Product Coke Plant. C. F. POGACAR AND E. A. TICE. Paper 6th Annual Conference, National Association of Corrosion Engineers. St. Louis, Mo., April 4-7, 1950. *Corrosion,* **7,** No. 3, 76-84 (1951) March. See also Addendum: *Corrosion,* **7,** No. 4, 128 (1951) April.

This presentation covers aspects of corrosion in modern by-product coke plant, cites results of corrosion tests in the various processing steps and describes uses of corrosion resistant alloys in some of the newer units. The corrosion data presented have been collected through the use of spool corrosion tests in plant equipment under conditions of normal plant operation. Coal-handling equipment and plant building suffer rather severe atmospheric corrosion. The advantages of low alloy steels for such applications, and the use of protective coatings derived from coal-tar products are mentioned. Most of the paper is devoted to a discussion of materials of construction for equipment, beginning with the evolution of the gas in ovens and ending with its storage in gas holders. A great deal of steel and cast iron can fortunately be used for handling ammonia liquors and for gas treatment. In the ammonium sulfate "saturator" the use of both Monel and Type 316 stainless steel have shown advantages which should lead to their continued use. In the process of light-oil recovery and refining, sulfuric-acid washing and

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light-oil distillation offer possibilities for the use of alloy materials. Coke quenching cars require frequent maintenance and replacement. To date, economics have necessitated the use of ordinary steel for the car structure and abrasion-resisting steel for the sloping floor. Also discussed are the construction materials for primary coolers, gas exhauster, tar precipitators, ammonia stills, and dephenolizing towers.

8.4.3, 6.2.4, 6.2.5

"On the Beam" Pumping. J. S. FULLER. Oil Well Supply Co. Paper before Oilfield Tech. Soc., Calgary, Canada, Aug. 28, 1950. *Petroleum Engr.*, **22**, No. 13, B27-28 (1950) Dec.

Discussion of the need for proper tools, abrasion, corrosion and impact in regard to pumps, and selection of sucker rods in the oil producing industry. Tubing pump barrels are of cold drawn steel or cast materials to resist abrasion. Brass, Monel and chromium-plated steel are also used. The hardest materials offered for bottomhole barrels and plungers are the boron-iron castings. The boron-iron alloy has good corrosion resistance except in hydrogen sulfide environments. Hydrogen sulfide and carbon dioxide are the chief causes of corrosion in wells. 3½ nickelsteel is the best material for use in carbon dioxide corrosion. Nickel-molybdenum steels of the SAE 4600 series are used for sucker rods. A 3½ nickel-molybdenum-manganese rod is used to offset hydrogen-sulfide corrosion. Where mild corrosion is encountered, high nickel-manganese-chromium-molybdenum steels and high nickel-manganese-molybdenum steel are utilized. Illustrations are given.—INCO.

8.4.2, 7.2

New Method Used to Lay Underwater Gas Line. P. REED. *Petroleo Interamericano*, 7, No. 6, 54-56 (1949) June.

The laying of a 13 mile underwater pipeline from an offshore gas well in the Gulf of Mexico by the Lavaca Pipeline Co. is described. Yard coated and wrapped pipe was welded into 1000 foot sections on stills. These were joined into 5000 foot sections on dollies placed on launching tracks, the string being towed seaward by tugs after the addition of each section. The 5000 foot sections, with attached pontoons and river clamps, were welded at sea to the line. The ends being welded were held above water by the boom of a dragline and an outrigger mounted on an LST boat. Details of the well, control, and metering equipment are included.

8.4.3, 4.6.9

Problems of Water Injection in Wells and Corrective Methods. Part II. Chemical Problems in Salt Water Injection. L. C. CASE. Gulf Oil Corp. Revision of paper, ACS, 114th Meeting, St. Louis, Sept. 6-10, 1948. *World Oil*, **128**, No. 12, 142-4 (1949) Mar.

Chemical problems encountered during the injection of waste oil field brine into disposal wells do not differ greatly from those in water flooding. Chemical relationships as well as physical factors are somewhat more favorable to salt water injection. Data on individual salt water injection wells are summarized in tables and discussed. After years of operating disposal wells, it is now indicated that proper selection of disposal formations and use of semi-closed or closed systems make brine coagulation and filtration unnecessary. It is possible to predict from laboratory analyses that certain brines will tend to deposit calcium carbonate and sulfur when aerated, while others will tend to deposit hydrated oxides of iron; the degree of precipitation, however, may not be predicted. Sludge deposits in brine injection systers in general have constitutions corresponding to the chemical nature of the water being injected and accompanying physical conditions. Three typical analyses are tabulated. A troublesome sludge observed where formaldehyde is used to combat corrosion in wells is thought to be derived from a reaction between hydrogen sulfide and formaldehyde.

8.5 Group 5

8.5.3, 6.3.10, 1.3

The Use of Nickel Containing Alloys in the Pulp and Paper Industry. H. O. TEEPLE. *Paper Trade J.*, **131**, 28, 30-32 (1950) Nov. 9; 19-23 (1950) Nov. 16; 14-15+ (1950) Nov. 23.

Reviews literature on corrosion of the above in contact with papermaking materials and solutions. Discusses choice of alloys for specific applications. The alloys discussed include not only the nickel-base group, but also the stainless steels and the nickel-alloyed cast irons. Data are tabulated. 80 references.—BLR.

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8.8 Group 8

8.8.1, 4.3.3, 4.4.8, 6.2.5, 2.2.3

Corrosion in the Ammonolysis of Aliphatic Chlorides. R. S. TRESEDER AND R. F. MILLER. Paper, 7th Ann. Conf. Nat'l. Assoc. Corrosion Engrs., New York, N. Y., March 13-16, 1951. *Corrosion*, **7**, No. 7, 225-228 (1951) July.

Corrosion data are presented relating to a process for manufacture of methallylamine by the high pressure liquid phase ammonolysis of methallyl chloride. Relative corrosion resistance of a number of alloys has been determined for the two most severely corrosive process streams encountered, one involving essentially an anhydrous solution of ammonium chloride in liquid ammonia and the other a mixture containing methallylamine and unreacted aliphatic chloride. The two systems have been found to have similar corrosion characteristics. Study of other combinations of amines and aliphatic chlorides has revealed such combinations to be generally corrosive to carbon steel and other common alloys under moderately high temperature conditions.

8.9 Group 9

8.9.3

Methods and Materials for Protection of Underground Pipe Lines. H. E. GRAHAM ET AL. *Bull. Am. Ry. Eng. Assoc.*, **490**, No. 225 (1950) Nov.

No type of protection suitable for all conditions and method selected depends on economics involved. Bituminous and petroleum-base coatings with chromate rust inhibitor have proven satisfactory under some conditions, as well as Portland cement mortar.—EL.

8.9.3

A Corrosion Control Program. L. A. KELLOGG. Niagara Mahawk Power Corp. *Gas Age*, **107**, No. 5, 11-3 (1951) Mar. 1.

The corrosion control program applied to a 19-mile natural gas pipeline from Syracuse to Fulton, N. Y. is described. The pipe was coated successively with coal-tar enamel, glass fiber wrap, coal-tar enamel, asbestos and kraft paper and cathodic protection installed.

8.9.3, 6.6.8, 6.6.6

Fiberglas-Plastic Oil Pipelines—How Soon? K. TREIBER. *Oil Forum*, **3**, 509-511 (1949) Nov.

Plastic pipe, made of 20 foot wide woven fiberglas cloth impregnated with thermal-setting polyester resin, not only weighs less than any of the other pipe line materials, including aluminum and magnesium, but is non-critical. Silica, its basic fabrication material, is one of the commonest elements in the earth's crust and the basic resinous materials are all of domestic origin. Tests to date of this material show burst pressures averaging 2200 psi. Tests involving 4 foot samples of the 6 inch pipe with 0.132 inch walls, using 91 octane gasolines at 1000 psi have indicated that the pipe is non-porous. After 150 hours continuous test the pipe showed no hint of delamination or other defect. When ready for shipment, the pipe will be fitted with 61ST aluminum ends. Materials and qualities of the 6 inch fiberglas-plastic pipe are listed, along with probable cost figures.

8.9.3, 2.3.4, 2.3.5

Field Reconditioning of a Large Diameter Pipeline. A. B. POLLEY. Pacific Lighting Corp. Paper, Pacific Coast Gas Assoc., Transmission Conf. San Francisco, May 19, 1949. *Gas*, **25**, No. 9, 101-102+ (1949) Sept.

A 76-mile portion of Pacific Lighting Corp.'s 26-inch pipeline from Kettleman Hills to Long Beach, Calif., laid in 1931, is being reconditioned to insure future uninterrupted service. Sections varying from 3.9 to 15.0 miles have been reconditioned by "over the ditch" operations each summer since 1944 without seriously affecting the overall line capacity. The pipe is raised, cleaned, sand blasted, spotwelded to cover small pits or replaced with new pipe in severely pitted sections, air-tested for leaks at 100 psi, simultaneously recleaned and primed, coated, electrically tested for coating continuity, and reinstalled in a redug trench. Many improvements in equipment and technique developed in the course of these operations are described. A conventional gasoline-powered travelling cleaning machine was equipped with knives instead of gears for the initial cleaning (the old coating filled the gear teeth) and with brushes and a primer head for the recleaning and priming. Replacement of steel propelling gears with rubber coated dollies in the coating machine eliminated damage to the primer coat and provided better traction, making possible use of the machine on steep slopes. Average pipe replacement to date has been 7.6 percent. Total costs not counting overhead have been $3.42 per foot. A cost breakdown is given. This type of reconditioning is feasible only where the line location is such that there is sufficient clearance for the operation of the necessary construction equipment.

8.9.3

Maintenance of Oil Pipe Lines. A. M. HILL. Stanolind Pipe Line Co. *Petroleum Engr.*, **21**, No. 3, D7-10 (1949) Mar.

A discussion of oil pipeline maintenance, including the organization and duties of the pipeline maintenance crews is presented. The types of leaks usually encountered, including the external and internal pit leaks, collar leaks, coupling failures, split joints, accidental punctures, and weld failures are examined with special emphasis on their causes and the methods used to prevent and repair each type of leak.

8.9.4, 4.6.10

Testing Inhibitors of Brine Drippings Corrosion of Railway Tracks and Equipment. G. M. MAGEE. Paper, 7th Ann. Conf. Nat'l. Assoc. Corrosion Engrs., New York, N. Y., March. *Corrosion*, **7**, No. 6, 185-188 (1951) June.

A joint committee from the Engineering and Mechanical Divisions of the Association of American Railroads has been sponsoring research work for some years aimed at finding a means of preventing damage from refrigerator car brine drippings to the tack, ridges and car itself. Initial studies indicated addition of sodium dichromate neutralized with soda ash to the salt and ice in the bunkers of the cars would effectively prevent corrosion from brine drippings. However, because of toxicity of the dichromate it was found necessary to add the inhibitor externally of the car by passing the brine drippings through a suitable filter in order to avoid contamination of the lading. Further work indicated development of such a filter was possible but the cost of servicing filters on each refrigerator car made the use of dichromate appear questionable economically.

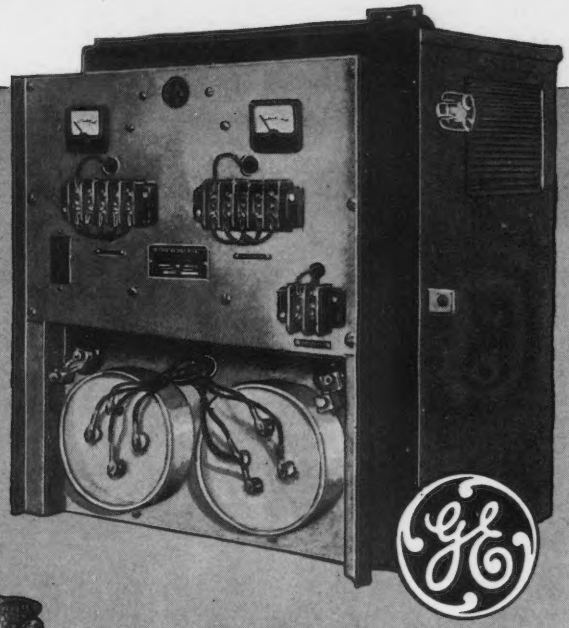
Studies with other inhibitors more recently developed have indicated Sodium Polyphos (the trade name of a glassy phosphate, intermediate in composition between sodium hexametaphosphate and sodium tetraphosphate) will be equally effective from the standpoint of preventing corrosion, and since it does not have the undesirable toxicity, it can be added directly with the salt. The cost of sodium polyphos as an inhibitor is not much greater than dichromate for equal protection, so it appears it will offer much more economical means of controlling corrosion. Additional work is necessary to determine the most effective inhibitor concentration and most economical method of application.

INDEX TO ADVERTISERS

Vol. 8 July, 1952 No. 7

	Page
Aluminum Company of America	i
Amercoat Corporation	Inside Front Cover
American Chemical Paint Co.	ix
Bakelite Company, Union Carbide & Carbon Corp.	25
Bechtel Corp. and H. C. Price Co.	9
Barrett Division, Allied Chemical & Dye Corp.	15
Brance-Krachy Co., Inc.	29
Corrosion Directory	17
Cathodic Protection Service	16
Cooper Alloy Foundry, Inc.	31
The Dampney Company	35
Day, S. D. Company	ix
Dow Chemical Company	ii
Electro Rust-Proofing Corp.	4
Federated Metals Division, American Smelting & Ref. Co.	7
Gensco Chemical Division	8
Good-All Electric Mfg. Co.	x
Harco Corp.	xiii, 49
H. M. Harper Co.	12
Hill, Hubbell & Co., Division of General Paint Co.	50
Johns-Manville Sales Corp.	13
Koppers Company	vi, vii
Mayes Brothers, Inc.	27
Metallizing Engineering Co., Inc.	23
Michigan Pipe Company	36
Monsanto Chemical Co.	xi
Mutual Chemical Co. of America	42
Natasco Co., The	26
National Association of Corrosion Engrs.	11, 28, 30, 46, 47
National Carbon Company, Union Carbide & Carbon Corp.	20
Nicolet Industries, Inc.	41
Pennsylvania Salt Mfg. Co.	19
Pittsburgh Coke & Chemical Co.	Inside Back Cover
Plastic Engineering & Sales Corp.	14
Polyken Industrial Tapes, Division of Bauer and Black	39
Positions Wanted	11
Royston Laboratories, Inc.	45
Saran Lined Pipe Co.	37, 43
Service Engineers, Inc.	44
Standard Magnesium Corp.	3
Standard Pipeprotection Inc.	11
Stearns, D. E. Co.	Back Cover
Tapecoat Company, The	33
United Chromium, Inc.	5
United States Stoneware Co.	22
Wilbur & Williams Co.	34
Williamson, T. D., Inc.	xii
Wright Chemical Corp.	40

SELENIUM RECTIFIERS and ELECTRODES



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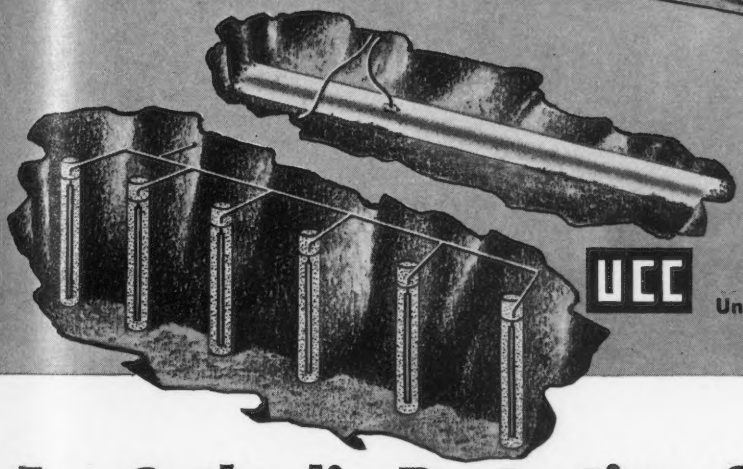

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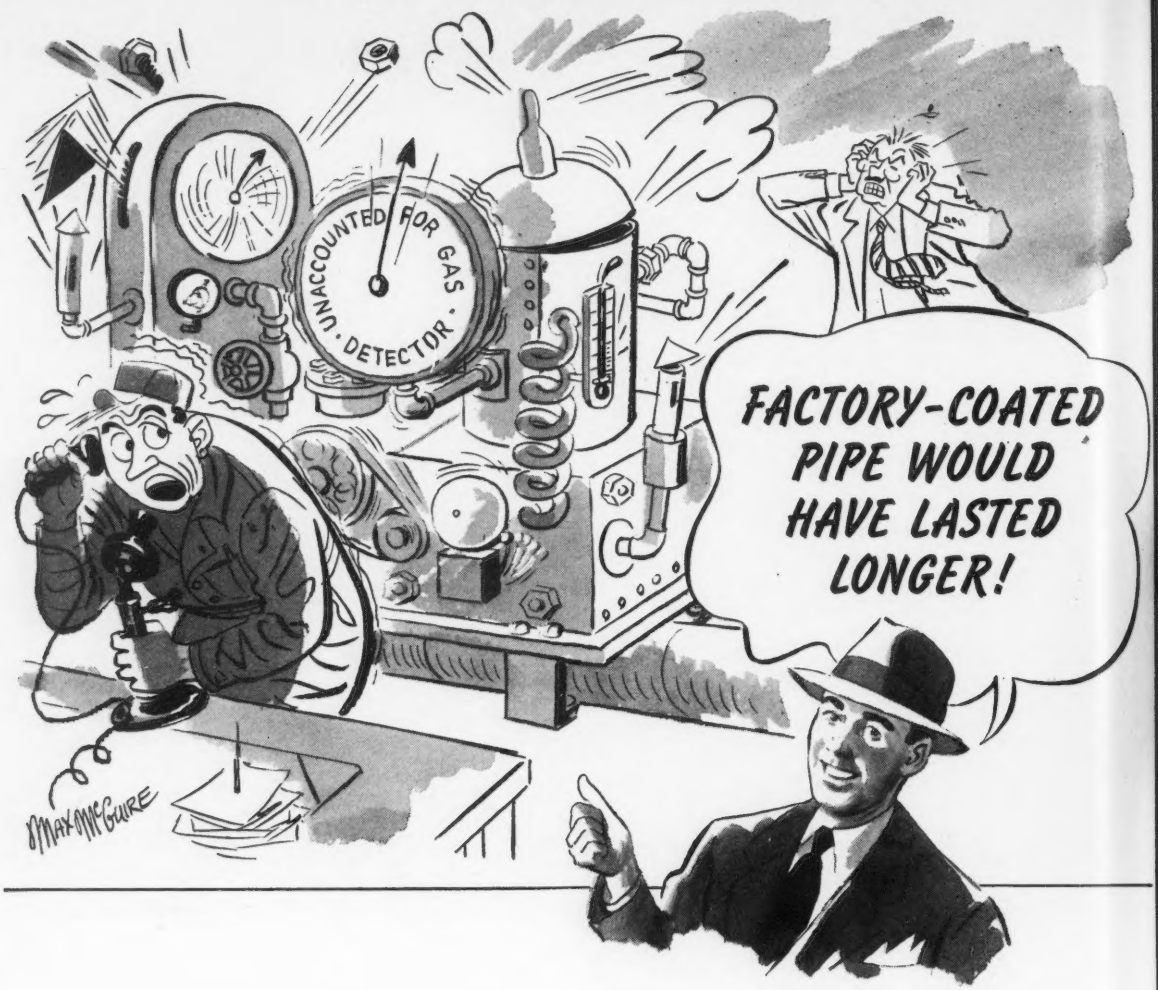

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